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SYMPOSIUM: TRENDS IN THE TEACHING OF GENERAL CHEMISTRY

FOREWORD

The teaching of general chemistry is now in a rapid state of flux. The worthwhileness of much of traditional general chemistry is being seriously questioned or is even being abandoned. Many experienced chemistry teachers are asking themselves how far they should go in adopting the newer concepts of general chemistry. Many teachers question a presentation of chemistry which largely excludes its historical development as a science. Then, too, there is evidence to show that alert young people with abilities for science demand something more challenging than traditional chemistry. This is borne out by the fact that enrollments in chemistry have sharply increased where college science courses have been modified to emphasize by actual use recent concepts and developments in chemistry.

The symposium, "Trends in the Teaching of General Chemistry," held at The University of Akron, 11 April 1958, was planned to highlight the important changes now occurring in the presentation of general chemistry. Our speakers were teachers with long experience in presenting chemistry to freshmen. They came from a variety of environments. Two came from small liberal arts colleges, two from large universities, one from a prominent institution for training scientists, and one came from industry after having had a successful university teaching career. There were many requests to have the proceedings published.

The success of the symposium can be attributed to the challenging ideas presented by the invited speakers and the large attendance from the colleges and universities throughout the state. The discussion following the presentation of the formal papers contributed further to the success of the symposium.

The officers and members of Section G, Chemistry, of The Ohio Academy of Science express their great appreciation to the speakers, to those who supported the symposium financially, the National Science Foundation and the Pittsburgh Plate Glass Corporation, Pittsburgh, Pa., through courtesy of Dr. W. S. Straub, Columbia Southern Chemical Corporation, Barberton, Ohio, and to The Ohio Journal of Science for publications of the proceedings.

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A SINGLE GENERAL CHEMISTRY COURSE FOR SCIENCE AND NONSCIENCE STUDENTS

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When chemistry curricula are discussed, the general chemistry course is usually assumed to be merely the first one of a sequence of chemistry courses leading to a major. When liberal arts curricula and the place of science in the curriculum are discussed, a common assumption appears to be that a course in the history of science, the philosophy of science, or a scientific method is appropriate. I wish to avoid the two extremes and to discuss a general chemistry course which can stand on its own merits as a course for college students regardless of their future major.

In colleges, departments other than chemistry have taught and still teach basic courses for all who are interested. A beginning course in English is taken by the science student as well as by the nonscience student. A student who wishes to learn a foreign language expects to study the language itself and not a course on the history or philosophy of the language. The student in economics or government courses expects to learn, in passing, the technical vocabulary used in these fields but he expects primarily to acquire a knowledge of economic or political problems. Similarly, a beginning student of chemistry should expect to acquire some chemical vocabulary, but he should be primarily interested in chemistry itself—the kinds of things chemists know and the present limits of chemical knowledge.

In a time of rapidly growing chemical knowledge static surveys emphasizing the memorizing of a highly selected body of material are no longer adequate. The freshman has just come from the secondary schools where memorizing of information and repeating of the information in tests and examinations were major parts of his scholastic achievement. He was not expected to inquire into or be interested in the basic premises of the subjects he was studying. But, in the freshman year in college he is introduced to a new intellectual environment. The time and place seem to be appropriate for a new approach to knowledge.

In many general chemistry courses the opportunities for the new approach have not been utilized. The students who go on to take more advanced chemistry courses are not seriously handicapped by a traditional course because in the later courses they will have the opportunity to examine the fundamental ideas in chemistry. But not all students take the later courses. May not one of the weaknesses of the past preparation of some high school teachers of chemistry be this—that the courses they studied in college were informational extensions of the high school chemistry course. Unless they completed a chemistry major they never did get enough chemistry to find out how chemists really think and act.

We must face the fact that only a rather small minority of those who study general chemistry become chemistry majors and complete the full chemistry curriculum. What can we do for those who at most study only one or two years of college chemistry? This question is of more than trivial importance in a time when science is playing an ever increasing role in our society and when educated people of all fields need to know more about it. Teachers of general chemistry in a college have a responsibility to these students. If the teachers do not rise to this responsibility, they will be passed by and the teaching of the sciences to the students at large will be done by others.

Before a mature person examines any problem in detail he looks at the problem itself in its setting. The chemist, with his interest in all material wherever it is and in whatever form it is, has the unique opportunity to take the broad view.

But, study of acids, bases, and salts, and of their water solutions, a major part of many general chemistry courses, can hardly be called broad. Even the future major who will examine the various aspects of chemistry in detail in later courses has the right to expect his general chemistry course to be general enough to give some notion as to what his future work will be.

What should be included in a modern general chemistry course? The course should really be general and not inorganic chemistry. It should start with basic ideas. At first, for pedagogical reasons, the ideas will be applied to rather simple cases but appropriate illustrations can be and should be found in all fields of chemistry. Every teacher who applies current chemical ideas to chemical problems easily brings his students to the limits of chemical knowledge where present theories are not adequate. This situation is not to be deplored; it is to be exploited. For one of the first facts a student of chemistry should learn about it is that chemistry is a growing and developing science. The nonscience student will surely not be educated if he does not understand this.

Among the basic, unifying ideas in a general chemistry course are: (1) the existence of atoms in bulk material; (2) structure of atoms (including that of nuclei and electronic fields), ions, and molecules (where they exist); (3) structure of bulk material: of elements and their compounds, and of natural materials, whether in pure gas, liquid, and solid phases, or in solutions; (4) relations between chemical composition and structure; (5) the periodic system as a correlating device for structure, size, and reactivity; (6) chemical bonding and electronegativities; (7) changes in bonding (chemical reactions), energies, and rates; and (8) chemical equilibrium. These concepts are to be applied and used to interpret the behavior of real substances.

If the student is to learn to interpret the fundamental ideas in terms of real behavior, he must have the facts available to him, for chemistry is still an experimental science as well as one with a theoretical framework. Sources of the facts will be descriptive material in the textbook or in reference material and the laboratory experience of the student.

A very general complaint of chemistry teachers is that the textbooks are too large. They are certainly too large if the student is expected to memorize all the material in them. If descriptive material is used as it should be—that is, as something to be read and referred to when necessary and as a statement of stubborn facts to which theories may be applied and tested—it becomes an aid to the student's understanding rather than an additional, unwelcome assignment. Much of the descriptive material can be in tabular form. Then relations may be more easily seen. For example, a good table of oxidation-reduction half-reactions is very helpful to the student who knows how to use it.

I have been emphasizing the understanding of basic ideas in terms of a knowledge of fundamental chemical theory. But chemistry is an experimental science. It is actual substances which react and not a set of symbols on the blackboard or on paper. Demonstrations are useful, but as far as most students are concerned they still represent reactions at a distance. There is no substitute for individual laboratory work, for it is only in the laboratory work that theory and fact really meet. Every teacher has before him a concrete illustration of the difficulty students have in understanding chemistry when he sees students who can write chemical equations easily on an examination paper having trouble writing the equation for a reaction which has occurred under their eyes in the laboratory.

Laboratory work, if properly planned, becomes a practical experience in the scientific method. Laboratory time is too valuable to be used for pencil and paper exercises. Adult chemists go to the laboratory only when they have a problem which an experiment is needed to solve. Laboratory work in a general chemistry course should also involve some element of the unknown for the student. Students generally rate quantitative experiments, such as those involving titration and the

use of the analytical balance, and qualitative analysis unknowns, as the experiments they enjoy most. Both types involve unknowns and are therefore inherently interesting. They give the student a sense of really working in a science. If he is to do the experiments well, he must do some thinking of his own. Many students even become interested in technique because good technique helps them. The student who never takes another chemistry course but who has analyzed some unknowns in the general chemistry laboratory will have developed sophistication about tests and proofs which he could not otherwise acquire.

The need for good laboratory work spread throughout the school year places some restrictions on the order in which topics are introduced in the classroom. At first glance this restriction may seem highly undesirable. The teacher may feel that the needs of the laboratory interfere with a logical order in the classroom. But an order which may seem logical to one who knows a science may not seem as logical to the student who studies the science for the first time. A logical order in a textbook is a linear order; one topic follows another in sequence. But many topics are cross-linked. For example, one cannot really understand everything on page 10 of the textbook unless he knows some of the material on pages 130 and 260. Theory, and especially new theory, is not learned overnight. One needs time in which to develop self-consistent theories and to test them with known facts.

It is, I believe, a mistake to throw too many new ideas at a student at once. I am more than willing to sacrifice some logical order if the student feels a sense of progression as he goes from idea to fact and from fact to idea. The practical requirements of a laboratory can keep one from going too fast. Indeed, many ideas are best developed on the basis of the laboratory observations of a student. "Here are the facts; how can they be interpreted?" This is a question the student faces and one we should face with him.

I have not discussed the teaching of chemistry as a historical science, as a device for teaching "scientific method," or as an introduction to the philosophy of science. Some topics, but not all, may well be treated from an historical approach. Certainly, a knowledge of how ideas develop is essential if we wish to anticipate how present ideas will develop in the future. The scientific method can only be understood by one with some experience in a science. The whole general chemistry course provides experience and should be a practical exposition of scientific method: honesty with the facts, recognition of the power of theory, cultivation of the inquiring, questioning mind, development of initiative and imagination. Then the student will know that chemistry is a growing science, that it will change in his lifetime but that not all aspects of it may be expected to change to an equal degree. He will be able to follow new developments as they are reported in the popular press and to know just what experimental facts or what new developments of theory are involved.

In the meantime, the future chemistry major has not been neglected. He will be impressed by the broad view of chemistry and by the variety of its applications, by the power of theory, by the limitations of present ideas, and by the need for future work. In the laboratory he will have developed habits of good observation on which he could draw meaningful conclusions. As introduction to the later courses in organic chemistry, analytical chemistry, and physical chemistry he will have a general setting for the more intensive and quantitative considerations. And if he still wants to be a chemist, it will be because he has a good notion of what he is getting into

THE USE OF QUANTITATIVE AND QUALITATIVE ANALYSIS IN THE GENERAL CHEMISTRY LABORATORY[1, 2]

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The work of the freshman year at the California Institute of Technology is uniform—students taking basic courses in mathematics, physics, chemistry, English, and history. At the end of this year students preregister for the sophomore year and for the first time must select a professional option which consists of a sequence of courses leading to a degree in one of the fields of science or engineering. Since the end of World War II, there has been a continued decrease both in the number and in the average quality of the students electing at this time to enter the options in chemistry and applied chemistry. Even after taking into consideration the present glamour of physics and electronics, this decrease has appeared to be abnormally large. In fact there seemed evidence that the laboratory work of the freshman chemistry course was neither attracting the interest of the students in general, nor holding the interest of those who had been previously attracted to this field. In seeking an explanation of this situation three somewhat related questions emerged.

First, to what extent was the conventional laboratory work of the general chemistry course still unduly influenced by the period when chemistry was predominantly a descriptive science?

Secondly, since substantially all of the freshman students at the Institute have had high school chemistry of some type, to what extent was the laboratory work repetitive of this work and therefore lacking in providing either stimulation or evidence of progress.

Thirdly, to what extent was this laboratory work failing to recognize that both science and engineering are becoming progressively more quantitative in both theory and practice?

It is true that there had been an attempt to introduce more quantitative experiments into the freshman laboratory work. Experiments making use of Mohr burets and analytical type balances with a sensitivity of approximately one milligram had been introduced into the work, but there was little evidence that these experiments had proved to be particularly effective in increasing the interest in the work. In fact the introduction of this pseudo type quantitative work in the freshman year caused the work of the quantitative course in the sophomore year to seem frustratingly repetitious and monotonous, and the necessity of correcting some of the habits formed in the previous year intensified this feeling.

As a result of these considerations a committee from the Division of Chemistry and Chemical Engineering, composed of John Roberts, Carl Niemann and the author, was asked to consider a revision of the work of the freshman year and, if it appeared appropriate, of the entire undergraduate chemistry curriculum.

After considerable discussion, within the Committee and with other members of the faculty, this committee recommended that an experimental program be initiated in which the conventional laboratory work of the first two quarters of the freshman course was to be replaced by selected quantitative experiments

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[1]A report on the revised curriculum at the California Institute was given at the Symposium on New Ideas on the Four-Year Curriculum during the September, 1957 meeting of the American Chemical Society in New York City. This report was published in the Journal of Chemical Education, 35, 248 (1958). The author is indebted to Dr. William F. Kieffer, editor of that journal, for his generous permission to make extensive use here of material from that report.

[2]Contribution No. 2342 from the Gates and Crellin Laboratories of Chemistry, California Institute of Technology.

essentially the same as those which had been given previously in the sophomore course in quantitative analysis. This recommendation was based upon several assumptions and the committee was uncomfortably aware that the validity of these assumptions could only be demonstrated by resorting to the experimental method.

The first of these assumptions was based on the belief that at the present time freshman students, especially those with an interest in science or engineering and with the motivation to have taken a preparatory course in chemistry, were sufficiently mature to be more interested and challenged by quantitative laboratory work done on a professional level than by such work when it was reduced to the status of a pedagogical device. Also, it was believed that such students would be challenged by the opportunity of checking their own technical competence and achievements against professional standards and against the achievements of their fellow students.

The second assumption was based upon the belief that it would *not* be significantly more difficult to teach such freshman students quantitative techniques than it had been to teach these techniques to sophomores. In fact, it was believed that these techniques would be more interesting and challenging when they had not been preceded by similar work of a lower caliber. In addition, it was believed that these techniques could be so taught that they would illustrate the principles involved, not only in making quantitative analyses, but in making quantitative measurements with other instruments and in other fields of science and engineering.

Thirdly, it was believed that by a proper selection of experiments *the general principles of chemical reactions could be illustrated as effectively by such quantitative experiments as by the more descriptive and qualitative experiments generally used.* Finally, it was believed that the actual analysis of unknowns would prove more interesting and challenging to the student than would, for example, the determination of an equivalent weight which, as expressed by one student, ". . . had been determined fifty years ago fifty times more accurately."

The committee was aware that in general the quantitative analysis laboratory has not been noted for attracting students into chemistry. It was realized that the success of the course would be quite dependent upon the work being so oriented as to convince students, especially those without an initial interest in chemistry, that the objective of the course was not to train him to make analyses, but rather to give him some appreciation of the methods and the problems involved in making quantitative physical measurements regardless of the instrument used or whether these measurements were to be applied to chemical, physical, or engineering purposes. Also, he should be made to realize the value of this work in enabling him to develop a feeling for sources of error and for critically evaluating the validity of experimental data, regardless of its source. Above all, he should develop a respect for the experimental method and a realization that the experimental method is the basis of scientific progress. In recent years there seems to be an increasing tendency by students, both graduate and undergraduate, to avoid the experimental method. And this tendency seems to be accompanied by, or may result from, an inability to plan or execute experiments, to make pertinent observations, or to interpret those which are made. A further consideration leading to the recommendation to undertake this experiment was the fact that such an integration of the general chemistry and the quantitative analysis laboratory would achieve a substantial acceleration in the basic training of the student and thus would give him much more time in his junior and senior years, especially the latter, for undergraduate research or for more advanced courses in his field of special interests.

The freshman chemistry course at the Institute consists of two one hour lectures per week, given to the entire class of approximately 180 students; a one hour quiz period which is given to sections of approximately 20 students; and

two three hour laboratory periods per week. The lectures are given by senior staff members. During the first two quarters of the 1956–57 academic year one of the weekly lectures was usually given by Professor Pauling and was related to the material in his text, *General Chemistry*. The other lecture was given by Professor Harold Johnston and was related to the general principles, not the specific details, of the laboratory work.

This division of the lecture material was unfortunate, and this year all of the lectures of the first quarter were related to the laboratory work. They began with weight relationships, stoichiometry, units of quantity and of concentration, and then were directed towards the examples of chemical equilibrium involved in the laboratory work.

The so called quiz hour was in charge of the graduate teaching assistant responsible for the laboratory work of the section. The quiz period was used not only for quizzes but also for presenting and discussing the laboratory work in more detail and for answering questions related to either the lectures or the laboratory work. For want of a manual designed for this particular course, use has been made of elementary quantitative texts, freely supplemented by mimeographed material.

The laboratory work during the 1956–57 year began with use of the analytical balance and included methods for determining rest points, determinations of sensitivity with various loads, and a calibration procedure for weights from 1 to 5 gm. The student was then given calibration values for the entire set and he weighed an unknown object. This was followed by a conventional gravimetric determination of the chloride in a solid unknown; the silver chloride precipitate was weighed on either a sintered glass or a porous porcelian crucible.

Volumetric work was then begun and the student calibrated a buret at the 20 and 30 ml intervals. These weight and calibration procedures were not done as mere manipulative training but as a necessary means of establishing both the personal and instrumental capabilities and limitations involved in making a quantitative measurement. The corrections for air buoyancy and for temperature effects also illustrated the necessity for considering external variables. The students showed a surprising amount of interest in these calibration procedures. A standard silver nitrate solution was prepared by weighing the dried salt, dissolving it, and diluting it to volume. Following this a volumetric determination of the chloride in an unknown was made with chromate being used as the indicator. A potassium thiocyanate solution was then prepared and standardized against the standard silver nitrate; ferric nitrate was used as indicator. The thiocyanate solution was then used to determine the silver in an alloy or the mercury in an unknown solution. The final determination of the work of the first quarter was the identification of one of a series of compounds by means of the determination of the molecular weight by means of freezing point depression measurements.

In the second quarter the principles of oxidation-reduction reactions were illustrated by the preparation and standardization of a tri-iodide solution and its use for the determination of the antimony in a stibnite type ore. A thiosulfate solution was prepared and standardized and then used for the determination of the copper in an alloy.

Acid-base equilibria were then taken up and the laboratory work involved the preparation of hydrochloric acid and carbonate free sodium hydroxide solutions and a determination of their volumetric ratios. The sodium hydroxide was standardized against potassium acid phthalate. Determinations were then made of the concentration of acetic acid (vinegar) solutions and of the total alkalinity of various carbonate mixtures. At the end of this first year there was justifiable criticism of the preponderance of volumetric methods. Consequently, this year procedures involving colorimetric and simple constant current coulometric methods were introduced, along with the use of pH meters.

The laboratory work of the third quarter was shifted from quantitative measurements to qualitative analysis. This was done in order to exploit the unique potentialities of a system of qualitative analysis as a pedagogical device for teaching descriptive inorganic chemistry and the principles underlying chemical reactions. Because the pedagogical effectiveness of a system of qualitative analysis will be determined largely by the extent to which the major separations can be correlated with the fundamental properties of the elements and therefore with the Periodic Table, the system which was used was a simplified version of the one described by Swift and Niemann in Analytical Chemistry, *26*, 538, 1954. This system was developed at the Institute for use by the Chemical Corps during World War II and the initial step consisted of a fusion with sodium peroxide and sucrose in a Parr bomb. Upon treatment with water a residue remained consisting of those elements forming oxides which were sufficiently insoluble and basic in character to remain as a precipitate in the strongly alkaline solution. This residue was separated and termed the Basic Element Group. The solution was divided into two portions. One portion was analyzed for those elements forming predominantly amphoteric oxides; the other portion was analyzed for those elements forming predominantly acidic oxides. The system provided for the detection and for the volumetric or colorimetric estimation of thirty two elements. The pedagogical advantages of the initial separation into the three major groups seemed to justify an attempt to adapt it for class use and a simplified modification of the system has been used in mimeographed form at the Institute, and with classes at the University of California at Los Angeles, for the past five years. In this system the use of the Parr bomb has been eliminated by carrying out the fusion with sodium hydroxide and nitrate in a nickel crucible. Space does not permit a more complete description of this system in this article.

As mentioned above, this system has been used with freshman classes at the Institute for several years; however, the results obtained by the class last year were far superior to those of previous classes. These students had had an opportunity during the first two quarters to acquire a background of useful techniques and an understanding of chemical equilibria which allowed them to concentrate on the descriptive chemistry of the system. The author is convinced that the potential pedagogical values of the analytical chemistry courses can be more fully exploited by beginning with simple quantitative determinations, where both techniques and principles can be developed at a reasonable pace. The qualitative work can then be done on a more rigorous and quantitative basis with respect to both theory and practice, and with more time for treatment of descriptive material.

An objective and valid appraisal of the effectiveness of this approach to the freshman laboratory work is difficult to make at present. One has to be wary of conclusions drawn from these limited experimental data, especially when psychological factors are involved. All available evidence indicated that the interest and morale of the students during the first year of this work were much better than they had been in previous years, and this improvement has been maintained during the present year. This was true in spite of the fact mentioned above, that during the first year there was a lack of correlation and synchronization between the material relating to the general chemistry text and that of the laboratory. Also, partly because of this, the amount of material presented was such as to overload seriously the average student. In spite of this, at the end of that year the number of students electing the options in chemistry and applied chemistry showed an increase of approximately 65 percent over that for any one of the previous five years. Two other factors could have been partly responsible for this effect. First, both the instructors and the students were intrigued by the participation in an experimental program. Secondly, when this work was initiated, a senior member of the staff was assigned on a voluntary basis to each of the laboratory sections. He not only exercised general supervision over the work

of the teaching assistant, but was also to spend sufficient time in the laboratory to establish a personal contact with each of the students.

The results of the first year of this work appeared to justify continuing it on an experimental basis and this is being done during the present academic year. Certain changes have been made and it is expected that this will continue to be the case as more experience is gained. At the end of the second quarter a preliminary questionnaire indicated that there will be a further gain in the number electing the chemistry options at the end of the year.

As a result of the change in the freshman course, the basic course in organic chemistry has been shifted to the sophomore year and replaces the analytical course which formerly extended through that year. This year sophomores are taking this organic course together with juniors who are under the old curriculum; there appears to be no marked difference in the performance of the two groups. The basic course in physical chemistry will be given as formerly, throughout the junior year. In the first quarter of the junior year a more advanced course in quantitative analysis will be given. This will not be an instrumentation course, but will extend the work of the freshman year to more exact measurements in the laboratory and to a more rigorous treatment of complex equilibria and of separations in the class. This course will be followed in the next two quarters by a physical chemistry laboratory course. Thus, by the end of the junior year a student will have finished his basic courses. There will be no required courses in the senior year except for those in the humanities; these compose about one quarter of the academic load of each year. The student will thus be able to take either a significant program of undergraduate research, or approved elective courses of an advanced nature in his particular field of interest. Among these approved electives are advanced courses in mathematics or in other fields of science. A significant number of students are interested in combining work in physics, biology, or geology with their chemistry option. The flexibility of this new curriculum facilitates such programs.

A MODERN AND QUANTITATIVE PRESENTATION OF GENERAL CHEMISTRY

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The day that the first earth satellite was launched, it became fashionable to raise one's voice in a cry of alarm over the shocking state of the American educational system. I do not need to add my voice to this chorus or to suggest additional candidates for the role of THEY who are responsible for the mess we are in. Practically all the various groups have already been singled out for attack.

The colleges and universities: they have been coddling the students, and directing their own efforts toward building buildings instead of building men's minds.

The students: they are lazy, and are both unwilling and unable to put forth an honest intellectual effort.

The parents: they have failed to develop in their offspring a proper sense of values and have abdicated their traditional role of models to TV and Elvis Presley.

THE OHIO JOURNAL OF SCIENCE 59(1): 9, January, 1959.

The professional educators: by insisting that "how to teach" is more important than "what to teach," they have built an empire that is concerned only with perpetuating mediocrity.

The school boards: their lack of courage in the face of pressure groups has sapped the morale and driven thousands of imaginative minds out of the school system.

There is a great deal of truth to many of these charges, and it is a pity that courageous souls such as Joel Hildebrand, who have been telling us these things for years, were completely ignored until a Russian space dog started circling the earth. But, however true these charges may be, I am not willing to jump to the "obvious" conclusion: that the American system of education is in crisis and that it is inferior to other systems of education. Last year I was a visiting lecturer in France and I had ample opportunity to observe rather closely the workings of the "superior" continental system of university training. The completely unexpected conclusion I eventually reached—even with its curse of monstrous numbers, the American system of education is turning out a product which for imagination, curiosity, and ingenuity, is unrivaled in Europe. I think the American system is vigorous, healthy, and worthy of respect, and those who condemn it are paying too much attention to those who put a premium only on one's ability to perform mental gymnastics.

Not that we can afford to be complacent or that we can do without some improvement! There's room for quite a few giant steps and we as chemistry teachers can touch some of these off. One of the puzzling aspects of the general fault-finding and soul-searching that has been going on in the past six months is the apparent immunity of the teacher. If ever the stage were set for the "poor overworked, underpaid" teacher to become complacent, this is it. Actually, let's face it! If anyone is ever going to do anything about improving the American system of education, then it will have to be the teacher who does it. And the beauty of it is the teacher can do something constructive right away whereas, by the time the professionals come up with an answer to this problem, another problem will have taken its place. What I advocate (and this is the essence of what I have to say) is that we as chemistry teachers can do a lot to improve the American system of education simply by raising the standards in our courses and toughening them up. We have tried it at Cornell in our big freshman chemistry course and it works.

Every teacher is faced by a decision— what level of work should I ask of my students? How much material should I expect them to be able to handle? We posed these questions in overhauling our general chemistry course. The answer we suggested—let us ask our students to do a bit more than we think they can handle. Let us see how far we can push them. The amazing result—the more we asked of the students, the more they gave us. And they seemed to be better satisfied in doing so. The net result is that now our big freshman chemistry course sets a higher standard as a modern, quantitative presentation of general chemistry than many a course given to chemistry majors.

Certainly the increasing complexity of physical sciences demands that we put more into the freshman courses—more facts (for efficient operation) and more principles (for dealing with more complex unknown situations). Why do we hold back? The common answer is "the students can't take it. They are not so well-prepared as previously. We have to go slower." On the contrary, college students are better prepared to grasp ideas than they were previously. Also, they resent being coddled. Such treatment, when inflicted on them, embarrasses them. I'm sure other people have discovered this same thing—if we want college students to act like students we must treat them as students and not as children!

Furthermore, there are other ample justifications for higher standards and

tougher courses. One of these is sheer self-preservation. Freshman chemistry has become such a monster (always something being added, never anything taken out) that it is absolutely unmanageable unless there is a drastic overhaul in the direction of using to the full the powerful summarizing principles that a chemist uses as second nature. Another justification is that toughening our courses is about our only effective leverage on the high schools. So long as we make concessions to the high-school preparation and take over the instruction which rightfully should have been done in high school, the situation will get worse. Only when the high schools realize no remedial action will be taken at the college level (to plug holes in arithmetic, algebra, general science, etc.), then only will entering students come in with the proper skills.

What, then, does Cornell do in presenting a modern, quantitative course in freshman chemistry? First, the background. We have three courses (1) a terminal course devoted to those who want to know something *about* chemistry but who will take no further courses in the field, (2) an accelerated course including qualitative analysis for chemical engineers and those definitely decided to be chemistry majors, and (3) an introductory course which assumes no previous knowledge of chemistry but which eventually serves as prerequisite for following chemistry courses. This third course is by far the largest (1100, compared to half as many in the other two combined) and is the one which concerns us here. On the average it breaks down into 400 engineers (mechanical, electrical, civil, and engineering physics), 250 agriculture students (those who will need more chemistry, as in soil science, dairy industry, etc.), and 450 arts students (pre-meds, undecided chemistry majors, and humanities people in search of broadening themselves). The backgrounds range all the way from no previous chemistry to two years of rather high-level experience in high school. The course is presented as two 50-minute lectures per week (in groups of 350) and one 3-hour laboratory-discussion per week (in groups of 20).

Our philosophy has been to teach chemistry (fundamentally on a framework of principles) as it really exists to a modern-day chemist—that is, the choice of terms, models, and beliefs is what we think chemists hold to be true at present. By the same token, those points where chemists are now uneasy are also mentioned. The other guiding principle has been to teach in such a way as to require no unlearning in a subsequent course. For example, the material on gases includes enough on nonideal behavior so that a nonideal gas will not come as a shock in physical chemistry as it did to many of us. The other main principle in our philosophy is to emphasize the distinction between "a fact that is observed" and "a property of a model that is being used to explain that fact." We believe that much of the trouble in making the transition from high school to college and from freshman courses to following courses stems from a failure or inability to distinguish clearly between a fact and an explanation. Many are the students who have come to me with the remark "then what my high school teacher told me was wrong?" In most cases, the student is referring to a property of an outmoded model (for example, the circular tracks of the electrons in the planetary model of atoms). In his confusion of "explanation" with "fact" he believes he is being asked to throw out facts—certainly a demoralizing prospect.

Throughout the course, our approach is quantitative, with a considerable emphasis on problem-solving and on giving, so far as some severe limitations permit, a quantitative expression to the properties of some of the models (e.g., kinetic molecular theory). In order to make the quantitative approach feasible, we have introduced two innovations to take the burden off the usual assigned problem sets and exercises. One of these has been to section the students for their discussion-laboratory periods according to mathematical ability. During the first week of the course, the students take an examination covering in part simple arithmetic and algebraic operations and in part so-called word problems. From the results of these tests, the students having laboratory at a given time are separated so that

the top 20 are in a section by themselves, the bottom 20 in a section by themselves, and the rest are distributed at random. The reason behind such sectioning is that it permits the low section to concentrate on simple mathematical aspects which are of no interest to the top section. On the other hand, the top section can spend its discussion time on more sophisticated topics. Feeling as we do that we owe a special responsibility to keeping our good students working to the limit of their capabilities, we assign senior staff men to lead the discussions in the top sections with the strong implication that they will push the discussion as far as possible. Thus, the top students are not inflicted with the 20-minute discussions of how to read a graph or what a logarithm is that the poor students find so interesting. Similarly, in his own milieu the poor student is not bashful about asking the simple questions that honestly bother him (and probably his fellow students).

The other device for increasing mathematical competence is the problem session. At strategic places in the course, laboratory experiments are replaced by organized but informal problem-solving sessions at which students work at the blackboard on a mimeographed set of interrelated problems. The instructor is always there to give immediate assistance where needed. These sessions have proved to be immensely popular. Certainly they are useful because they have allowed us to add quantitative depth to our course. A not unwelcome dividend is that the problem sessions add flexibility to the laboratory scheduling problem, particularly when the lecture material for several consecutive sessions does not lend itself to experiments (e.g., atomic theory).

As far as the material covered is concerned, we spend the first term in developing the principles of chemistry in order of increasing complexity—the atom, the chemical bond, states of aggregation, solutions, kinetics, and equilibrium. A surprisingly large body of descriptive material can be woven in as illustrative material, and I suspect that by using to the fullest extent the organizing principles, our students end up with as much knowledge of descriptive chemistry as if they had taken a traditional course (This point may be important in trying to sell a principles approach to the engineering and agriculture administrators.) In the second semester, the chemistry of the elements and their compounds is discussed at a rather high level in terms of the principles previously developed. The order is hydrogen, oxygen, aqueous solutions, and then from left to right across the periodic table. We have abandoned the traditional right to left treatment for several reasons. First of all, group similarity is much more strikingly illustrated by the alkali metals than by the halogens. (For the halogens, I often get the feeling the similarities and group trends are more pronounced in the text books than they are in the laboratory. Rare is the student who comes out of freshman chemistry with a correct idea of the chemistry of fluorine, for example.) Secondly, it is convenient to have metallic properties highlighted first so that it does not become necessary to interrupt the discussion later with perhaps the false implication of a clean-cut distinction between metals and nonmetals. Thirdly, beginning with metals has the advantage of getting rapidly into elements generally unfamiliar to most students. They stay more interested early in the semester because of the unfamiliarity of the metals and can be kept interested later in the semester since the familiar elements such as sulfur and the halogens can be given more sophisticated treatment.

Actually, to appreciate the coverage in a course one needs more than an indication of topics covered. As an example of what we do, we can look at our treatment of chemical kinetics—almost invariably a mistreated subject in freshman chemistry courses. First of all, we keep a clean separation between kinetics and equilibrium so as to forestall the common misconceptions when these are treated together. In treating kinetics, we do not shirk the real problems as is often done by taking nonrepresentative cases. We face up to the full problem. Our approach, as customary, starts with the observed facts of kinetics—the fact that rates depend

upon factors such as concentrations and temperature. As a specific example we take the reaction

$$2H_{2(g)}+2NO_{(g)} \longrightarrow N_{2(g)}+2H_2O_{(g)}$$

for which the rate law is

$$\text{Rate}=k[H_2]\,[NO]^2$$

[It might be noted that we avoid that old tired horse of hydrogen plus iodine to give hydrogen iodide—one of the few cases for which the rate agrees with the stoichiometric equation. Better we should face our students with early recognition of the fact that in general the rate law exponents are not deducible from the coefficients of the stoichiometric equation.] Then we proceed to discuss the elements of collision theory and how the observations can be interpreted. The idea of stepwise reaction with one step acting as a rate-determining step is not ignored and in fact actual mechanisms are proposed for the above reaction. For example, we indicate that the above rate law would be consistent with the following steps:

$$(1)\quad NO_{(g)}+NO_{(g)}+H_{2(g)} \xrightarrow{\text{slow}} N_2O_{(g)}+H_2O_{(g)}$$

$$(2)\quad N_2O_{(g)}+H_{2(g)} \xrightarrow{\text{fast}} N_{2(g)}+H_2O_{(g)}$$

where (1) is rate-determining. However, we point out, many people object to this mechanism because it requires a three-body collision (2 molecules of NO and 1 molecule of H_2)—a rather improbable event. Some people, we say, prefer the following steps:

$$(1)\quad 2NO_{(g)} \xrightarrow{\text{fast}} N_2O_{2(g)}$$

$$(2)\quad N_2O_{2(g)}+H_{2(g)} \xrightarrow{\text{slow}} N_2O_{(g)}+H_2O_{(g)}$$

$$(3)\quad N_2O_{(g)}+H_{2(g)} \xrightarrow{\text{fast}} N_{2(g)}+H_2O_{(g)}$$

which, after all, add up to the same net reaction but do not involve a three-particle collision. Then, by using the fact that the rate of step 2 is proportional to the concentration of N_2O_2 times the concentration of H_2 and that the concentration of N_2O_2 is directly proportional to the square of the concentration of NO (step 1), we can come out with the observed rate law. Needless to say, our presentation is not on a very sophisticated level but it does put the essential points across and it does not breed a host of misconceptions that will need to be unlearned in following courses.

What about the laboratory? Here our thoughts have been bounded by considerations of space and money limitations. Obviously one thinks twice before requiring a fifty-cent item for a student when it must be multiplied by 1100 students. This is one of the reasons qualitative analysis has not been made an integral part of our second term laboratory. Instead, what we have tried to do is to draw on a large number of quantitative experiments—using where possible the added stimulus of unknowns. Thus, for example, we ask our students to determine the atomic weight of an unknown metal, which they do by determining its gram-equivalent weight. This is straightforward and is a classical experiment. But they need the specific heat. Instead of giving them the value, we have them determine it by a simple calorimetric method. The result has been that an experiment previously "dry-labbed" now takes on a personal character for each student since only his instructor knows the identity of his unknown.

Similar modifications have been made in other classic experiments. For example, instead of doing an experiment to "verify" Boyle's and Charles' laws we have our students extend the same experiment so that they determine absolute

zero. They get amazingly good results and, what's more important, feel as though they were really doing science. Another experiment involves the study of the rate of iodide-catalyzed decomposition of hydrogen peroxide. Unlike the classic iodine clock, which gives an integrated time that is almost impossible to interpret, the hydrogen peroxide decomposition enables the student to measure the oxygen at successive intervals as it is being evolved, thus enabling him to extrapolate back to zero time and find out how, for example, changing the initial concentration of iodide changes his results. The idea of a rate law takes on a real meaning. Other experiments are similarly quantitative and include such things as analyzing an unknown for sulfate content, determining what happens to the oxidation number of sulfur when $S_2O_3^{=}$ reacts with I_2 to convert it to I^-, analyzing soap for water content, determining what fraction of burning magnesium goes to Mg_3N_2 and what fraction goes to MgO, etc. All of these experiments are done with usual freshman equipment, but the precision in many cases is startling. To us it indicates that in the laboratory as in the lecture when students are challenged, they produce better than we expect them to.

Well, what have been the results of our tougher, stiffer approach? First, the course has gained increased stature among the student population. Students now say, "It was a tough course but I enjoyed it," instead of merely shrugging their shoulders as they did previously. Second, it has resulted in an increased effort on the part of the students. I sometimes suspect that the average student will do 75 percent of anything you ask him to; so, you had better ask a lot more than you really want him to do. Thirdly, there has been an increased interest in chemistry as a major. About half of our chemistry majors come from this large course and apparently are drawn mostly from those who are undecided between chemistry and physics. Toughening our course has made chemistry more appealing to those who are attracted to the elegant precision of physics. Fourthly, the morale is better among our teaching assistants. They work harder but with more motivation. It is true that many graduate students come to us so poorly prepared that as teaching assistants they find it difficult to keep ahead of the freshmen. But their invariable remark—"I wish I had a course like that as a freshman." Finally, the gratifying result is that the idea is spreading to other courses. Physics and zoology are tightening up their introductory courses and even the agriculture school is getting concerned about raising standards.

Not that we imply all our problems as being resolved. We still have not solved the problem of how to ease the painful first 6 weeks for the student who takes our course without any previous experience in chemistry. He has a rugged time of it at first (primarily, I think, because of the demand of quickly developing a large specialized vocabulary). My only satisfaction is in the observation that these students usually turn out eventually to be better than average possibly because the pressure is on them to develop good study habits early. The other unsolved problem is what to do with the students who come to us with extremely good high school preparation. Obviously, you say, give them advanced standing. This we try to do, but there are two odd problems. Most of those who get advanced standing do not take advantage of this by starting in with an advanced chemistry course (in other words, we never get a crack at them as potential chemistry majors), or they refuse to take advantage of the possibility of getting advanced standing. It is an unfortunate thing that many of our students are so used to playing it safe that they are more willing to be bored for a whole year and get a good grade than to try something daring and run the risk of failure.

There are other problems which I foresee for the future which may be more serious. One is technical and involves the supply of teaching assistants. If the government, as it seems probable, steps up its fellowship program significantly, then we shall be faced with the awkward situation of having the good graduate students not available for teaching duties. A possible solution is to require each

fellowship holder to teach for 3 hours. This will be inefficient because preparing to teach one laboratory section takes as much time as preparing to teach three laboratory sections. An alternative solution would be no fellowships for first year graduate students. The other problem is more general and probably less likely to be solved. It is summed up in the description given by Dr. Polykarp Kusch, Professor of Physics at Columbia and Nobel laureate in 1955, after a visit to Dartmouth College as a visiting professor. After lecturing to a class of 180 undergraduates, he described his impression as follows, "one-third had a deep, lively interest; one-third had good manners; one-third had neither." Evidently some of these people don't belong in college. I'm not sure I want to commit myself on which of the last two groups is dispensable.

In conclusion, I would like to make a special plea to chairmen of chemistry departments—a plea not to consider freshman chemistry as "taken care of" if it causes no administrative trouble. Aside from the fact that tuition-wise it usually brings in the biggest chunk of money, freshman chemistry merits special consideration for two reasons: (1) it is *the* course in which the future attitude of the country toward chemistry is being shaped and (2) it is *the* course in which we have the most direct possibility of strengthening the future quality of our profession as chemists.

ATOMIC ARCHITECTURE FOR THE GENERAL COLLEGE CHEMISTRY STUDENT

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The approach used in presenting atomic structure to the first year college chemistry student is predicated upon several factors: 1. a very early presentation of the subject, after introduction of principles of units (fundamental and derived) and stressing of dimensions in the realm of the ultraminute; 2. a reasonably complete picture at this early stage, on the assumption that a usable working model will be developed; 3. an attempt to capture interest in the chemical area rather than devoting time at an early stage in the physics-chemistry borderline area of kinetic molecular theory; and 4. introduction of the subject in a fashion which allows a maximum of reasoning by the student and a minimum of memorization in order to understand chemical and physical behavior of the elements and their compounds. The descriptive chemistry of the elements discussed later in the course, the reactions of qualitative analysis, the principles of acids, bases, amphoterism, solution, conductivity, complex ion formation and many other topics are then developed by considering the electron distribution within atoms. It is obvious that size and charge relationships also play an important part in the discussion of these topics. These relationships are continuously stressed.

The student body to which this presentation has been offered should be defined: 1. Students both with and without high school chemistry background. Approximately some 15 to 20 percent have had no high school chemistry. 2. Students in a state supported institution, with an enrollment in the order of 26,000. The entrance requirements are such that any student in the upper 50 percent of his high school class may be admitted. 3. Students with major interests in virtually any field excepting chemistry, chemical engineering, and other fields of engineering. The majority are in the premedical, predental, prenursing, and agriculture cur-

ricula. Actually, a similar approach in presenting chemistry is used with the chemistry majors. 4. Class size of approximately 250 with four or five such sections being taught.

The essential points, then, in the development of atomic architecture that are presented very early in the course are briefly summarized: 1. experimental evidences for fundamental particles; 2. experimental evidences for relationships between the nucleus and the extra nuclear portion of the atom; 3. nuclear particles and atomic number; 4. experimental evidence for the electron arrangement through spectroscopic observation; and 5. the arrangement of electrons and their designations by four quantum numbers in terms of energy levels is finally developed. These lectures on atomic structure are followed by a systematic presentation of the periodic table and the classification of the elements on the basis of atomic number. This is accompanied by a thorough consideration of types of chemical bonds, both as to similarities and fundamental differences.

The types of materials covered in the unit on atomic architecture will be mentioned principally in topical form by referring to a number of figures. This material is presented by a combination of lectures, lecture demonstrations, the use of lantern slides, and with "chalk-talks." The manner of the intensive treatment of these topics will vary somewhat depending upon the composition of the various groups and the needs of the lecturer.

The main areas of the problems involved in studying the atoms of elements systematically are presented in the following steps.

I. The importance, nature, and behavior of the electron is developed through discussions based upon—

1. The Millikan oil drop experiment (fig. 1).
2. Information derived from the vacuum tube in magnetic fields. The concept of canal rays comes also from vacuum tube experiments (fig. 2).
3. The x-ray tube and the concept of bombardment of a target by electrons resulting in x-ray emmission. This observation fits nicely into later discussions relating energy of light to electron excitation and return of electrons to normal states (fig. 3).

II. The general observations of particles and energy from radioactive materials (fig. 4).

III. Particles derived from atomic nuclei. These particles are more or less dogmatically described as coming from the nucleus at this point, with evidence to be presented later (fig. 5).

IV. Moseley's Law and the relation between x-ray wave length and mass of the nucleus, in turn related to proton content of the nucleus (fig. 6). The point is stressed that the chemical behavior of an element is a function of the proton number since the number of electrons and their final arrangement will be related to this value.

V. The neutron and its derivation by a nuclear reaction:

$$^{9}_{4}\mathrm{Be}+{}^{4}_{2}\mathrm{He}={}^{1}_{0}\mathrm{n}+{}^{12}_{6}\mathrm{C}.$$

The treatment of this topic includes a brief discussion of the history of the discovery and the unusual properties of this nuclear particle (fig. 7).

VI. The positron and its derivation by a nuclear reaction:

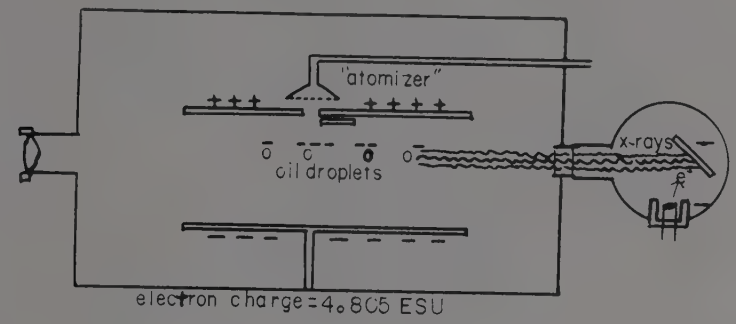
$$^{10}_{5}\mathrm{B}+{}^{4}_{2}\mathrm{He}={}^{13}_{7}\mathrm{N}+{}^{1}_{0}\mathrm{n},$$

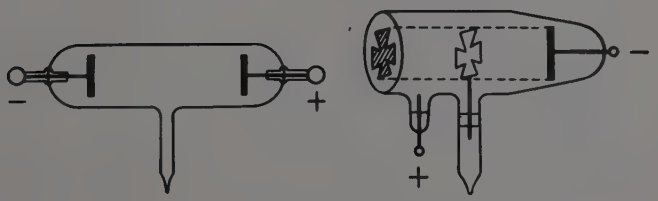
$$\longrightarrow {}^{13}_{6}\mathrm{C}+\beta^{+}\ \text{(positron)}.$$

There is a discussion of "antiparticles" at this point. Thus, the positron is the antiparticle of the negative electron (fig. 8).

VII. The Rutherford gold leaf experiment: The great importance of this experiment, surprising in its fundamental simplicity, is discussed as showing for the first time the approximate sizes of atoms and nuclei. There is a qualitative discussion of the experiment to show that gold atoms have nuclei about 4 x 10^{-12} cm in size, and that most of an atom must be empty space (fig. 9).

VIII. The concept of the spectrum of an element obtained with spark and arc-activated elements and a spectrograph. This discussion is accompanied with





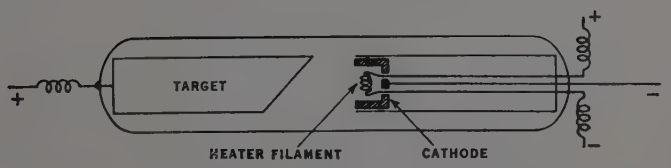


FIGURE 1. Millikan oil drop experiment.
FIGURE 2. Studies with cathode ray tubes.
FIGURE 3. The x-ray tube (Coolidge type).

demonstrations of flame tests (fig. 10). Chalk-talk techniques are extensively used at this time to bring out the following concepts:

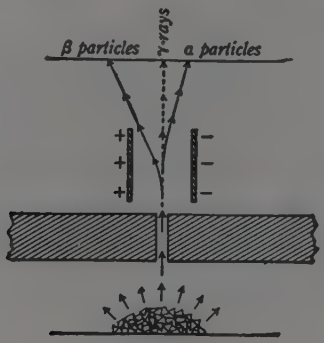
1. General concepts of the wave nature of light and the relation of energy to wave length.
2. The concept of activated electrons within atoms and the release of energy as electrons drop from outer to inner orbits.
3. The concept of the principal quantum number (fig. 11).

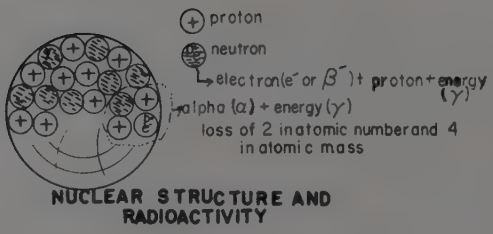
IX. The need for additional energy levels to account for the multiple lines

of the spectrum (fig. 12). At this point there is consideration of the second quantum number and the designations of the subshells.

X. The third quantum number. The element sodium is used to bring out the meaning of the third quantum number (fig. 13).

XI. The fourth or spin quantum number. The discussion brings out the fact that all the electrons in any given atom have an "address" no matter how




proton
neutron
electron(e⁻ or β⁻) + proton + energy (γ)
alpha (α) + energy (γ)
loss of 2 in atomic number and 4 in atomic mass
NUCLEAR STRUCTURE AND RADIOACTIVITY

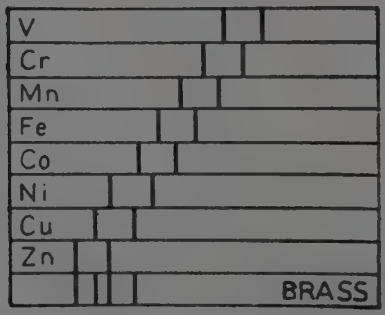
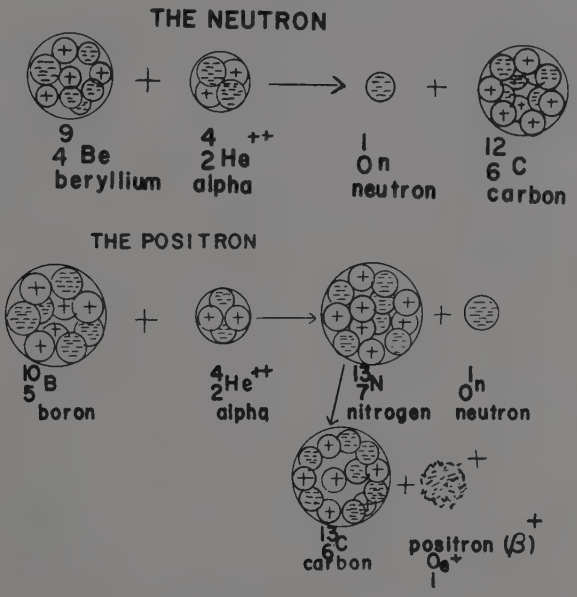


FIGURE 4. Radiations from radioactive subtances.
FIGURE 5. Particles derived from nuclei.
FIGURE 6. The contribution of Moseley.

large the atomic number. It is pointed out that no two electrons can have the same address or state. This is a way of stating to general chemistry students that no two electrons in the same atom can have the same four quantum numbers (fig. 13).

XII. The development of the first transition series follows at this point after having developed the structures of the elements through calcium (fig. 14). The apparent inconsistency of chromium is not stressed; though the $4s^1$, $3d^5$ arrange-



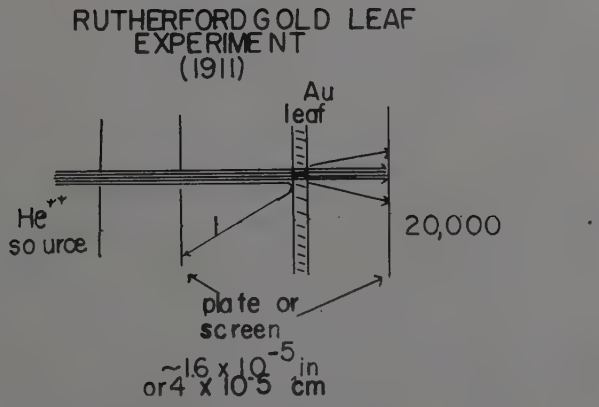
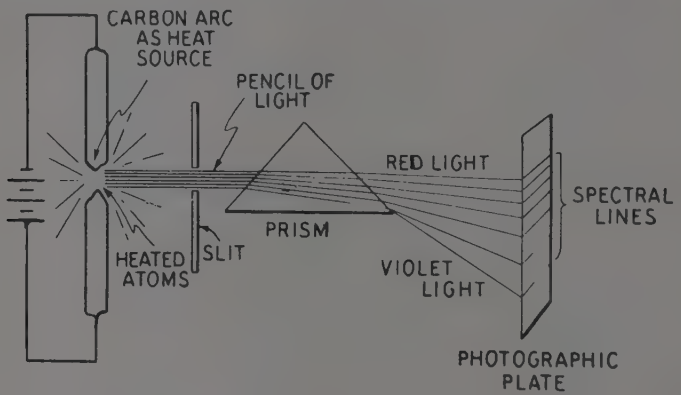
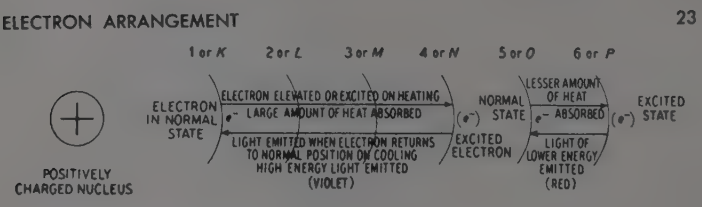


FIGURE 7. The neutron.
FIGURE 8. The positron.
FIGURE 9. The Rutherford gold foil experiment.

ment should not be unexpected considering the effect of the increasing nuclear charge and the increased attraction for the electrons, making for the stable configuration with the differentiating electron in the 3d subshell. The Cr(II) and Cr(III) oxidation states become logical as does the Cr(VI) (fig. 15).

Some knowledge of the spin quantum number has been found of interest even for the first year student. He is likely to wonder how we know that there is a





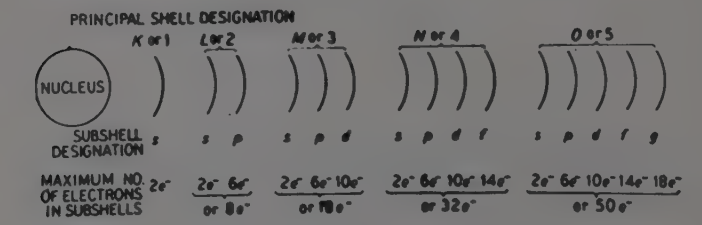


FIGURE 10. Schematic diagram of a spectrograph.
FIGURE 11. The principal orbits or shells of the atom showing electrons in normal and excited states.
FIGURE 12. The electron subshells of the atom.

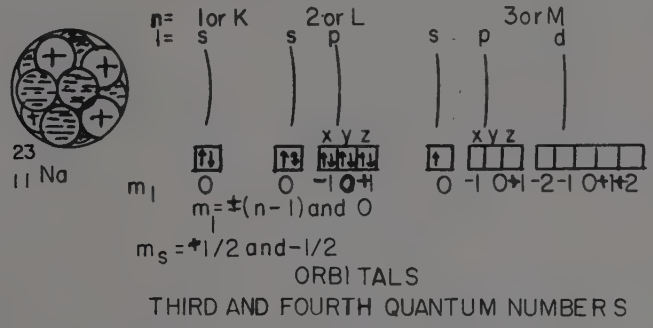
maximum unpairing in a given atom. The magnetic susceptibility measurement follows with no additional theory. Dia- para- and ferromagnetism of elements and their compounds are easily explained in terms of unpaired electrons.

XIII. The importance of filled and half-filled energy levels is then stressed

to account for the chemical properties of certain elements. Thus, the chemical properties of zinc and copper atoms can be contrasted with those of chromium and manganese. This is brought out in the following observations:

1. The zinc atom has a constant oxidation state of 2 because all its subshells are filled (fig. 16).

2. The oxidation state of Cu(I) is to be expected. The evidence for the Cu(II) state must be accounted for by the loss of a single 3d electron (fig. 16). The blue color of the Cu(II) ions as due to an unpaired electron can be mentioned. However it is reasonable to assume that a Cu(III) state is hardly to be expected.


n= 1or K 2or L 3or M
l= s s p s p d
x y z x y z
23
11 Na
m l 0 0 -1 0 +1 0 -1 0 +1 -2 -1 0 +1 +2
m l = ±(n-1) and 0
m s = +1/2 and -1/2
ORBITALS
THIRD AND FOURTH QUANTUM NUMBERS

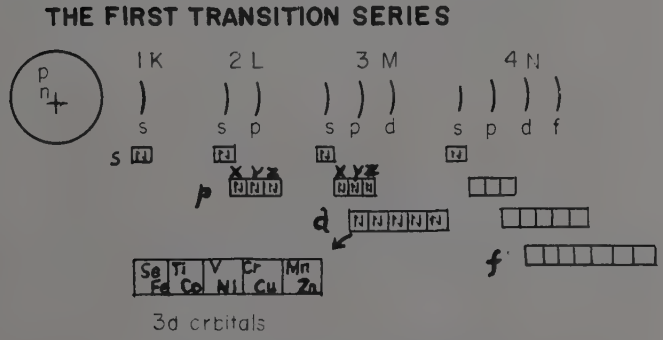


FIGURE 13. The third and fourth quantum numbers.
FIGURE 14. The first transition series.

3. The manganese atom serves as a good example for a number of points of chemical interest. It's relative inertness as a metal follows from filled and half filled subshells as well as the small size, in contrast to calcium with its strong electron donating potential (fig. 15). As the magnitude of positive oxidation state increases it is logical to believe that there will be less ionic nature to the bonds formed. The half filled orbitals make reasonable a certain amount of difficulty in attaining state higher than (II); however, all states up to and including (VII) are possible. Compounds in states above (II) are likely oxidizing agents, and auto-oxidation and reduction reactions can occur.

XIV. The use of ion-electron or half cell equations is initiated at this point for simple cases in the discussion of the loss or gain of electrons by atoms in the

formation of the ionic bond. A good example of the application of these ideas is the ionization of sodium with the resultant diminution in size from 1.86 to 0.95 Å (fig. 17). The student is then ready to understand the relative inertness of the sodium ion as due to the stability of filled orbital systems or paired electrons in the s and p subshells. This is much more meaningful to the student than an explanation based upon the octet rule. Thus a considerable body of information is derived through individual reasoning by the student, which is a distinct aid to

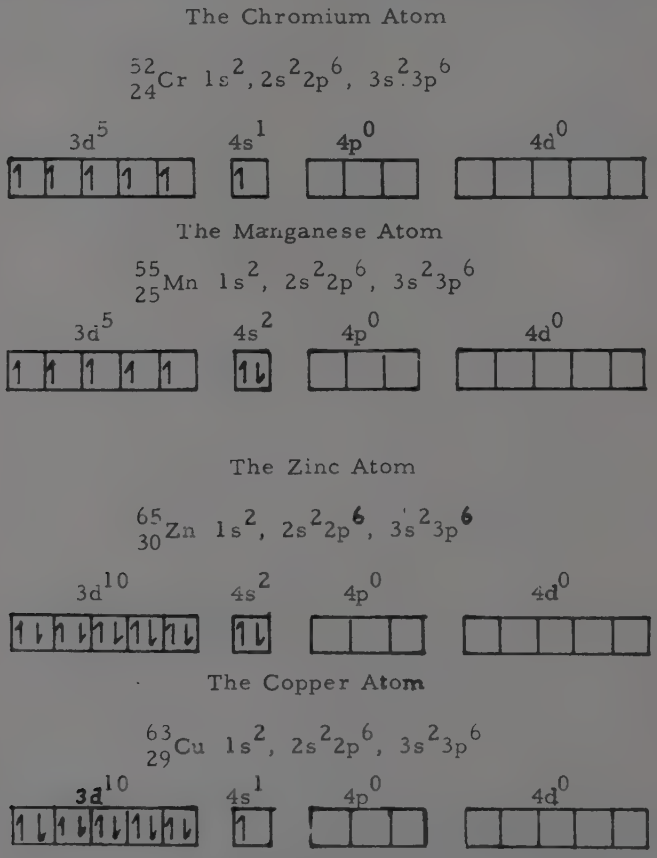

The Chromium Atom
$^{52}_{24}Cr\ 1s^2, 2s^2 2p^6, 3s^2 3p^6$
$3d^5$ $4s^1$ $4p^0$ $4d^0$
The Manganese Atom
$^{55}_{25}Mn\ 1s^2, 2s^2 2p^6, 3s^2 3p^6$
$3d^5$ $4s^2$ $4p^0$ $4d^0$
The Zinc Atom
$^{65}_{30}Zn\ 1s^2, 2s^2 2p^6, 3s^2 3p^6$
$3d^{10}$ $4s^2$ $4p^0$ $4d^0$
The Copper Atom
$^{63}_{29}Cu\ 1s^2, 2s^2 2p^6, 3s^2 3p^6$
$3d^{10}$ $4s^1$ $4p^0$ $4d^0$

FIGURE 15. Chromium and manganese as transition elements.
FIGURE 16. Comparison of the structures of atoms of zinc and copper.

the morale of the students. The subject of gaseous ionization potential is introduced at this point as a fairly quantitative and useful method for comparing the tendencies of metals to lose electrons and the reluctance of nonmetals to do so.

XV. The importance of the sizes of atoms in explaining chemical and physical properties of the elements is now pointed out by calling attention to the decreasing

size of atoms with increase in atomic number, say in the third series of the periodic table (fig. 18). The student has no difficulty in understanding the effect of the increasing nuclear charge on the attraction for the electrons which are all distributed within three main levels. From this time on the student is urged to resort continually to the use of the Campbell chart of the periodic table which shows the relative sizes of atoms and ions.

XVI. The stabilization of higher oxidation states is briefly touched upon at this point using the concept of available d orbitals. This topic as well as bonding in coordination compounds is not presented in any great detail at this time. However, the way has been paved for a fuller treatment in the third quarter in connection with qualitative analysis. In the third quarter, the student is also presented the concept of hybridization of orbitals. This is nicely introduced in discussing the structure of the carbon atom in methane, wherein a 2s electron is promoted to the 2p state permitting sp^3 bonding. The dependence of the structure or molecular aggregates are also discussed at this time. Examples are given of square coplanar (dsp^2 bonding), tetrahedral (sp^3 bonding) and octahedral (d^2sp^3 bonding) configurations.

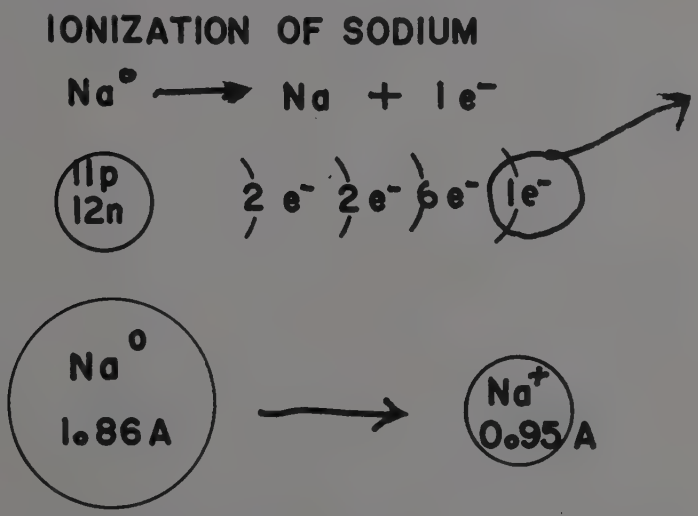
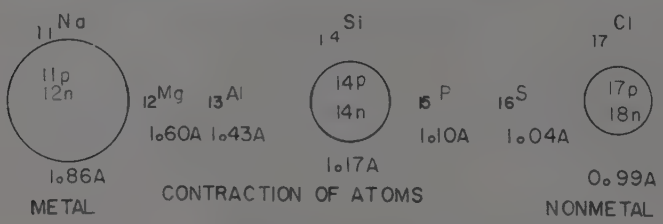


FIGURE 17. The ionization of sodium and a comparison of the sizes of the sodium atom and ion.

XVII. Acid-base relationships are explained right from the beginning in terms of the structural concepts of the central atom utilizing both Lewis and Bronsted theories (fig. 19). Thus, small metal ions with large positive charges may be shown to act as strong electron pair acceptors and therefore acidic or amphoteric in their behavior. The strong attraction of the metal ion for the oxide and resulting repulsion of the proton (as part of the hydroxide ion) gives a partial explanation of the capacity of such metal hydroxides to be amphoteric (or amphiprotic in this case). The same principles are carried through to the nonmetal central group (as S(VI), N(V), P(V)) when these atoms (in varying oxidation states) are associated with the OH group. The large positive charge and the very small size will further enhance the acidic behavior. The converse situation

with the large metal ions with small positive charge and resulting poor electron pair accepting property leads to the strong basic behavior or very weak acidic behavior.

As has been indicated before, essentially all the material outlined in Paragraphs I to XVI inclusive is presented as a total unit early in the course in general chemistry. This leads to a working model for studying the elements and their compounds which is applied throughout the rest of the course. Thus, the presence of a polar bond in water molecules is easily explained and the student is ready to accept and apply the concept of angular molecules polar in character (fig. 20).



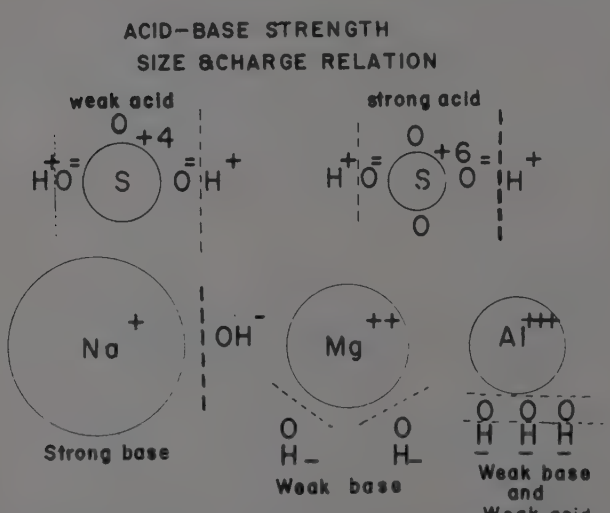
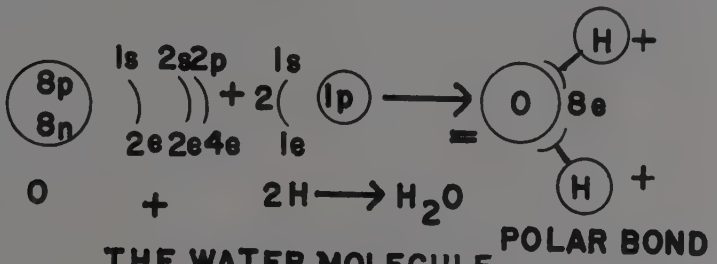


FIGURE 18. The effect of nuclear charge upon atomic size within same series in periodic table.
FIGURE 19. Acid-base strength relations to size and charge on central atom.

Students find this much more meaningful than to refer to water merely as HOH or H_2O. As a specific example of the many consequences of the polar character of the water molecule, consider the great differences in the behavior of methane (a typical nonpolar covalent molecule) and sodium chloride (a typical ionic compound) in water (fig. 21). Methane is a gas and but slightly soluble in water. Sodium chloride is a crystalline substance of high melting point but quite soluble

in water due to solvation effects dependent upon the polar character of the water molecule. The resulting solution, of course, is very different from the solution of methane in water. It is the feeling of our teaching staff that students, for example, can approach the study of the colligative properties of solutions with greater understanding using our working model than using the traditional physico-chemical approach employing Racult's law.

In conclusion, it is the prime purpose of this type of introduction to atomic architecture to give the student a working model, which it must be admitted is derived with many over simplifications, but which appears to have real teaching



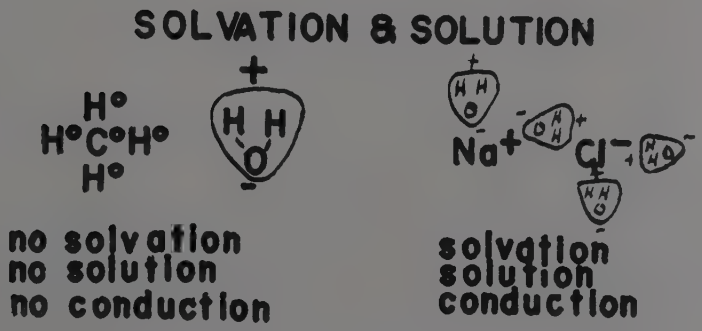


FIGURE 20. The shape and polar character of the water molecule.
FIGURE 21. Solution effects dependent upon the polar character of water molecules.

potential. An essentially identical model has been given to high school juniors, with sufficient success so that the feeling exists that we do not need to wait till a senior college course to develop a reasonably precise working model from the chemical point of view. Students going on in chemistry are in a good position to accept the more advanced postulates and theories of quantum mechanics, field theory, and other related topics. Those not continuing for a major but taking more chemistry courses and even terminal students, do not find such a presentation too difficult. The few extra periods devoted to structure at this early point pay large dividends in later portions of the course.

CHEMICAL BONDS IN THE FIRST YEAR COURSE

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In earlier times the first course in college chemistry was based on inorganic chemistry. It was one of a series of courses designed to present the sweep of the field of chemistry to the student who persevered. The subject matter was largely descriptive. During the past fifty years ideas about the behavior of chemicals have become increasingly fruitful. No systematic study of chemistry can then ignore these devices for organizing our descriptive knowledge. These ideas include: molecular theory, atomic structure, equilibrium, reaction mechanisms, and relation of properties to structure. As a result the first year course has largely become an introduction to these ideas. With this introduction the serious student then moves into subsequent courses for more detailed study of the phenomena of chemistry.

By and large the first year course has, during the past twenty or thirty years, become an introductory physical chemistry course. Unfortunately, it has not proved possible to present a particularly sophisticated study of chemical theory in this course so that each part of the course is then taken up again in later years by the continuing student. Few students majoring in chemistry will, at the end of four years in college, have much to remember from their first year course. At the same time the average student in the first year course finds it a rapid survey of a vast amount of conceptual material often presented in a rather disjointed way. Whether it makes any significant contribution to the liberal education of the general student is at least a matter for disagreement.

It is my contention that chemistry instruction would be much better off if this survey course called "General Chemistry" were abandoned. As presently taught it is often too superficial to present any really effective picture of how chemists think or work. Instead it overwhelms the student with a mass of detail. With the growth of chemistry in modern times the basis for choosing details to be presented becomes increasingly arbitrary.

Even casual inspection of the chemical literature reveals a prodigious expansion in the publication of information. The problem of organizing and retrieving information has become a central concern. Conceptual schemes can be a most useful key to organization, and fortunately chemistry is now in possession of a small number of powerful conceptual schemes with great scope.

Why not, then, use these conceptual schemes as the basis for a series of courses in college chemistry? This has the advantage that the number of concepts is relatively small and comparable to the number of semesters in a four year college program. Even more important, once selected they offer a basis for choice among the expanding welter of descriptive chemistry available. And still more important the system of conceptual schemes is an open one. The student can expect with some confidence to fit in many new laboratory findings as they develop. After all, the atomic theory is over two thousand years old.

Some may object that this can only be a program for the chemistry majors. What of our responsibility to the students of other sciences or, perhaps even more important, what of our responsibility to the general student? It is proposed here to take a portion of chemistry for study during the first year chosen to illustrate a particular major theory. This procedure will, of necessity, fail to consider many important aspects of the science. But this procedure will have the advantage of developing much more carefully the relation of a few ideas to a variety of chemical systems. This should make it possible to discuss with something more than superficial understanding the implications of these ideas beyond

chemistry. The general student should find it possible to get a clear understanding of how chemistry develops in a limited area. With this he should feel sufficient confidence to do whatever additional study his responsibilities may lead him into. It should be the aim of the course to give a real appreciation of the "tactics and strategy of science" of value not only to the major student but to the general student as well.

Chemistry is often defined as the study of the transformations of substances. It is concerned then with the properties of elements and compounds. Presumably, atomic theory should be used to account for properties. Atomic theory has been developed without assigning properties such as color, solubility, tensile strength, etc. to atoms directly. With the exception of mass, the properties of elements or of compounds are understood in terms of the bonds which hold the atoms together. Therefore, properties are thought about through consideration of bonds between atoms, and chemical reactions are thought about through consideration of the making and breaking of these bonds.

Earlham Chemistry Curriculum.—At Earlham we have conceived of the four year chemistry program divided into a series of courses each based on some major chemical theory. This works out fairly well into semester courses as indicated in the table.

Semester	*Main Concept*
First	Atomic Structure
Second	Covalent Bond
Third	Ions
Fourth	Chemical Energy
Fifth	Aromaticity and Resonance
Sixth	Kinetics and Reaction Mechanisms
Seventh	Advanced topics
Eighth	Advanced topics

The first two semesters, which take the place of a more conventional course called "General Chemistry," are limited primarily to a discussion of atomic structure, an introduction to the major types of bonds, and an extended treatment of the covalent bond. Throughout the course major emphasis is directed to the question of the relation of physical and chemical properties to bonds and the relation of bonds to atomic structure.

In discussing atomic structure we have found it useful to take the student into a treatment not only of shells and subshells but also into orbitals and the application of the Pauli exclusion principle to the pairing of electrons. With these considerations of theory the student is led to consider the periodic arrangement of the elements and to see how such properties as melting points, boiling points, hardness, and chemical reactivity are related to atomic numbers. Fruitful discussion is possible not only for the representative elements but also for the transition elements and for the inner transition elements.

To discuss systematically with students the relation between physical and chemical properties and atomic structure we have chosen to introduce various types of bonds. In fact we would argue that in a certain sense it is the bonds which possess the properties. Thus, the solubility of compounds containing chlorine is dependent for its explanation on the particular type of bond which unites the chlorine to the other atoms in the compound. Clearly the type of bond is determined ultimately by the kind of atoms involved but for simplicity of discussion, it seems necessary at this point in the development of chemical theory to make use of the bond concept.

Three prototype bonds are described: ionic, covalent, and metallic. These are presented as bonds produced by electrostatic attraction between charged atoms

where the atoms do not overlap, bonds where electrons are shared in pairs, and bonds between atoms where many electrons are shared among many atoms, respectively. In addition covalent bonds are discussed for cases where the electron sharing is equal and for cases where it is unequal, so that polar bonds can be described and the idea developed that ionic bonds and covalent bonds can be considered as extreme types of polar bonds. It is quite appropriate then to mention the distinctive role of hydrogen bonds, with this also tied to the concept of the polar covalent bond.

The general approach can perhaps be illustrated here by considering the properties of metallic sodium, gaseous chlorine, and their reaction product sodium chloride.

	Sodium	*Chlorine*	*Sodium Chloride*
Melting point, °C	97.5	−102.1	800.4
Boiling point, °C	892.	−34.7	1413.
Heat of dissociation, kcal/mole	(25.1)[a]	56.9	101.
Heat of vaporization, kcal/mole	25.1	4.4	40.2[b]
Water Solubility, moles/lit	reacts	0.09	6.1[b]
Color	silver	Greenish-yellow	Colorless

[a] It is assumed that all the sodium atoms dissociate during vaporization. Actually the vapor contains a small fraction of diatomic molecules.

[b] Formula weights are meant rather than moles.

Some comments on the reaction of sodium and chlorine to form sodium chloride may serve to show the method of presentation. A few properties of these substances are given above. Considerable point is made of the fact that the properties of sodium chloride are not, outside of weight, the sum of the properties of sodium and of chlorine separately. This dramatic and discontinuous change in properties that characterizes the reaction indicates that the two different elements are not behaving independently in their compound. An important chemical problem is to understand what it is about sodium and chlorine that does play a role in determining the properties of sodium chloride.

The values for sodium are rather typical of a number of metals and can be accounted for at least qualitatively in terms of metallic bonds between the metal atoms. Perhaps the most characteristic features are the color and the large difference between melting and boiling temperatures. The large value for the heat of vaporization plus the softness of the metal demonstrate the large forces that operate between atoms in the solid while at the same time the atoms can move around rather readily, so long as they do not move away from each other. Chlorine represents a quite different system which is understood in terms of discrete molecules formed from atoms joined in pairs through the sharing of electrons. These molecules or units, however, have relatively small forces between them and so the material is a gas at room temperature and with only a small interval between melting and boiling temperatures. This state of affairs is still further reflected by the small value for the heat of vaporization which requires separating only the molecules and the large value for the heat of dissociation which requires separating atoms. Thus, when sodium atoms with loosely held electrons and chlorine atoms with great attraction for electrons come together, the result is the formation of ions which then arrange themselves into a material with the properties listed under sodium chloride. The attractive forces possessed by the ions are large but nondirectional. This is reflected in the fact that the solid melts and boils only at quite high temperatures with a considerable range of temperature between melting and boiling while in addition the heat of vaporization is large. Further information is also introduced to indicate that the sodium chloride crystal is an ordered array of sodium and chloride ions whose gross shape is determined primarily by the geometrical problems involved in packing spherical ions together compactly.

It is hoped that this type of course will give the student insight into an important part of the logic of chemistry. This course cannot present the whole of the logic of chemistry but it can present that part which is concerned with the dependence of physical and chemical properties upon bond types within chemical substances. Our first year of experience with the course has been reasonably satisfactory. Student response has been good and students express particular interest in the question of the interrelations of the properties of chemical elements and their compounds.

OUTCOMES IN GENERAL CHEMISTRY

H. ZEISS

Monsanto Chemical Company, Dayton, Ohio

In coming to this Symposium from the research laboratory of a chemical company, I feel that I am obliged to present my credentials before speaking on the subject of outcomes in general chemistry. I do this at the risk of appearing to indulge in self-aggrandizement; but I shall take this risk since you will need to know what sustains my confidence in addressing myself to the topic.

As far as teaching is concerned you should know that I taught general chemistry at Yale for six years and that during this period of time something of the order of 300 freshmen sat in my classroom. Most of you are aware that in the past Yale has used the small section technique involving 20–25 students per class. During this period I was associated with upwards of twenty instructors who were also teaching on the freshman level, and I also had the opportunity of working with Professor Stuart R. Brinkley, a man of infinite patience and wisdom, who was in charge of the Freshman Year in Chemistry at Yale. I also taught organic chemistry to juniors, organic chemical theory and research techniques in the laboratory to graduate students, and had a dozen doctoral students in research in this period. So, what I lack in length in academic experience is in part made up by having run the gamut of teaching at both the college and university levels. The critique system in force at Yale proved invaluable to the instructors and certainly helped us correct annoying and distracting habits of which we were unaware. Under this system the freshmen at the end of the year were permitted to write down, in camera, precisely what their opinion of you as a teacher happened to be and then compared you with other instructors they had had. This could be both brutal and enlightening. In my experience none of the full professors were anxious to extend this practice past the first year students. But we of younger years profited greatly by it.

In 1955 I left Yale as part of an experiment dealing with the question of whether or not a basic research group can conduct free and unfettered research in an industrial atmosphere. However, this experiment is not the subject of my discussion here, but it is part of the background from which I shall draw. Another piece of background is my acquaintance with men who are undoubtedly leaders in our science and who are superb examples of creative, independent individuals of science. I speak of such men as Onsager, Kirkwood, Fuoss, and Doering of Yale; Kistiakowsky, Bartlett, and Woodward of Harvard; Pauling and Roberts of Caltech; Winstein and Cram of U. C. L. A., and others. I mention these men because I have made an attempt to observe them closely and have tried to see what makes them creative and useful in the science.

Before entering the main body of this discussion I wish to make also several cautionary remarks. Some of my statements will be severely critical, and I

want you to remember that these remarks as well as others are not based solely upon my experiences at Yale but also on my undergraduate years at Indiana, graduate years at Columbia and the year of work in German laboratories prior to the last war. In the same vein my industrial experiences are based upon contacts with Hercules, duPont, Union Carbide, G. D. Searle of Chicago, and several other smaller companies with whom I have been associated in the past. I'd like to proceed then with these points in mind.

First of all, let's talk about the first year of college and its effect upon the rest of the student's life. This morning Professor Steiner told you a great deal about the care and propagation of a superior student. This afternoon I want to tell you about the care and propagation of a mediocre student. I think that the figures are on my side and so let's see how you turn out a mediocre academic product. By "mediocre," according to Webster, one means "moderate" or "ordinary" but not "average." Educators don't know what an average student is and I don't either. So let's take a hypothetical student and march him off to college and let's further hypothesize that he's not been hopelessly maimed by his elementary and/or secondary education, and that he still retains a part of the natural curiosity and power of concentration with which every normal child is endowed and which become severely attenuated by the time he reaches college. Let me show you now how you may kill the last traces of these scholarly attributes.

We must look first at the college and ask if there is an atmosphere of scholarship—a tradition of intellectual achievement. There are some very fine schools in this country and I am proud to say that Ohio has its share of them; but there are also others, even some with heavily ivied walls, in which these traditions do not exist in spite of the lip service paid to them. Our freshman will discover this quickly, for he is at an impressionistic age and will emulate the upperclassmen almost immediately. In a college where scholarship is a lost cause, he will have learned to drift vigorously by the end of the first semester. Under such conditions we may easily understand what G. B. Shaw meant when he said that his education had been interrupted by his schooling. Of course, the atmosphere of a college is an ephemeral thing and certainly something which requires a number of years to change or create. And when we talk of a college, we are talking of its faculty, for it is the faculty which makes the college.

Our young man from high school, or prep school, meets his faculty and experiences his first collegiate emotional encounter. This adolescent is quite sensitive and is already under considerable strain from his transition from home to a new independence. And so what he finds in his instructors will have a profoundly subtle and intimate effect upon him. You are acutely aware in some instances of the emotional upsets which the student encounters. Now what does our student find in his instructor? A man who is tired, disillusioned, and disgruntled? But why tired? After teaching the same course for thirty years, why not tired? After reflecting on a number of ambitions unrealized in his science because of the press of his teaching duties, why should he not become disillusioned? And after a life of economic frustration, why not disgruntled? This man finds himself facing another year of teaching in the same course with the same old notes and in the same old rut. This is the man and instructor which our impressionable first year student encounters. The effect will of course be obvious and permanent. I strongly suspect that all of us can easily conjure forth the image of teachers who fit this description.

It is an unfortunate matter that in many of our colleges it is seen fit to entrust the education of the freshman to the "driftwood" and the inexperienced. And yet this is the level where the best teaching efforts should be made. It has been said that freshmen teaching is a fine place in which to break in the new instructors. Undoubtedly—and break the student too! By and large, the older faculty avoid the first year teaching loads like poison for the simple reason that this is one of

the hardest jobs available. I personally would rate it as the toughest one I've ever had and I include steel mills in my working experiences.

Quite recently, by way of illustration, the head of the chemistry department of a small but quite well-known eastern college offered one of my former doctoral students the post of assistant professor and the responsibility of reorganizing the freshmen program. This young man had had no teaching experience and in fact had been in chemical industry for several years but was anxious to enter the academic field. However, he didn't bargain for these terms and very wisely rejected this form of career suicide. The point is, however, that the chairman of this department was willing to turn over this course to a young, untried man. The whole situation is turned around. The first year courses are for men who are seasoned and who have demonstrated an ability to inspire and to create enthusiasm in the new college student. This is the place and the time at which our student is subject to hero-worship. We must make sure that he has a hero to look up to and to emulate. A fine teacher invariably will be found to be active in other areas of his science too, for this is a part of excellence. He will be publishing, writing, reading, and keeping alive in his field. You'll not find him devoted exclusively to the next selection of the Book-of-the-Month Club outside of the classroom.

I'd like to say a bit about the classroom which has been aptly described as the seminar of the mind. First, I would wish to eliminate the carnival or sideshow performances often called lecture demonstrations. This to me is a diversion and not an effective technique in teaching. This is not to say that an occasional single experiment which is both crucial and germane to the subject at hand is not valuable; but a common indulgence in pyrotechnics is not only an evasion of teaching, it can and has lead to the near annihilation, physical and mental, of freshmen in some instances. Instead, I would ask that in the classroom more emphasis be placed on reasoning and precision of thought. A number of my students, for example, were considerably shaken by the fact that a cubic centimeter is not equivalent to a milliliter and thought this difference to be trivial. It is true that the difference is small, but it is not trivial. Education which involves teaching inaccuracies such as the placing of electron orbits around a nucleus in the shape of a bull's eye is both shoddy and grossly misleading. It's true that many such ideas have to be taught initially in a qualitative manner. However, a qualitative matter and an inaccurate matter are two widely different things. Thus, shoddy reasoning, lack of precision in thought, and the teaching of inaccuracies will surely propagate a mediocre student.

The matter of getting through to the student in the classroom deserves some mention here. Jacques Barzun at Columbia expressed himself quite well on this problem when he spoke of teaching on the undergraduate level as being comparable to conducting a long distance telephone conversation to Cleveland in the middle of a cocktail party. By and large the easy way out is to simply get on with your lecture and let the words fall where they may, or you may attempt to get through by boxing the compass. By this I mean making as wide a range of appeal as you possibly can. As an example, I recall lecturing solidly for one hour on the subject of Pip in Dicken's "Great Expectations" in an effort to salvage a particularly recalcitrant English major. This maneuver was both surprising to the students and successful, for I got to this boy and secured his subsequent interest in the more germane aspects of the course. On the other hand I worry that I may have lost several chemistry majors in the process.

Professor Steiner spoke of the importance of the laboratory in the teaching of general chemistry. I should like to enter a very hearty second to this. If the classroom is the seminar of the mind, then the laboratory must be the seminar of the hands, of the experimental method, of the scientific technique. I would be perfectly willing, however, to see all the set experiments, such as the bubbling

of oxygen under water into those confounded inverted jars, go. The laboratory should become the center of the truly personal project. This is the place where the emphasis should be placed on letting the individual do his own work at his own pace. In fact, it is in the laboratory that the primary purpose of education can be most effectively achieved by training the student to educate himself.

In summation I wish to make several constructive remarks after some of the destructive ones I have given. I would suggest that we have less circus and more substance in the classroom; that more emphasis be placed on a seminar type of discussion at the expense of strictly formal lecturing; that all deans who insist on curve grading be boiled in oil; and that we demand more performance on the part of the student even at the expense of extracurricular activities. In the latter connection I denounce as doggerel those lines which give the impression that Britain's battles are won on the playing fields of Eton. This is an insult to the faculty of that venerable institution. I would suggest that we abolish all forms of spoon feeding and that the student be made responsible for his own academic progress. This, in my opinion, is one of the more attractive corner stones of the European educational system which has been neglected in ours. I would suggest that the laboratory be made the focus of special project work and the source of the development of scientific enthusiasm for the student.

With respect to able teachers of the subject of general chemistry, I would say that when you find one, surround him with assistants, take the paper work away from his desk, plaster him with Cadillacs and even import a harem if this is required to keep him happy. At all costs allow him freedom to teach. College offices must be transformed into business offices if they are to eliminate the inefficiency and waste of valuable time which impede the academician.

In conclusion I shall make the observation that a drastic improvement of the standards of first year teaching in the colleges will enforce the improvement of the curricula and standards of our high schools. The high schools will have to follow. This seems to me to be the only intelligent way in which to improve our educational system.

CHANGES IN BODY MEASUREMENTS OF HEIFERS AT FIRST PARTURITION[1]

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It is generally recognized that changes occur in some of the body measurements at parturition. Cattlemen are cognizant of the relaxation of the pelvic bones before parturition and the reduction in the circumference of chest and paunch after parturition. Little seems to be known about other possible changes except the swelling of the udder which causes an increase in the stifle measurement.

The changes in body measurements at parturition are of importance to those interested in the developmental phases of cattle. Information of this nature might be valuable for predicting certain details of show condition on an anticipated date and for interpreting research data. However, it is likely that the changes

[1]Journal Article No. 55-55, The Ohio Agricultural Experiment Station.

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may be of greater interest from the standpoint of physiological behavior. The present paper is concerned with a study of body measurements before and after first parturition.

EXPERIMENTAL PROCEDURE

The data used in this study were taken from a project concerning growth and development in cattle in which twins and triplets were the prime experimental subjects. A minimum of 18 body measurements were taken each week from time of acquisition of the cattle until at least one month after first parturition and then once a month thereafter. As a result, there are no comparable data for parturition subsequent to the first. A preliminary analysis of the data from the twins was undertaken and additional data on those measurements showing changes were collected on other heifers, singly-born, from the Experiment Station dairy herd to obtain more accurate estimates of these changes.

The twin animals used in this study consisted of one pair of monozygotic Guernseys, one pair of monozygotic Shorthorn x Guernseys, two pairs of Holstein-Friesians, at least one pair of which was monozygotic, one pair of monozygotic Brown Swiss twins, one pair of dizygotic Jersey twins, one Red Poll and one

TABLE 1

Model used in the analysis of variance

Source of Variation	D.F.	Composition of Mean Square
Between periods (P)	1	$\sigma^2_{WA}+3\sigma^2_{PA}+3a\sigma^2_{P}$
Between animals (A)	a-1	$\sigma^2_{WA}+3p\sigma^2_{A}$
Interaction between periods and animals (PxA)	a-1	$\sigma^2_{WA}+3\sigma^2_{PA}$
Between weeks within periods (W)	4	$\sigma^2_{WA}+a\sigma^2_{W}$
Between weeks within periods x animals or error (WA)	4(a-1)	σ^2_{WA}

Guernsey for whose twins similar data either were not available or were suspect because of illness. The nontwin heifers consisted of 4 Jerseys and 3 Holstein-Friesians, giving a total of 21 animals. These heifers calved from September through March of three different seasons at an average age of just over 2 years 2 months. Of the 21 heifers, 18 calved at ages from 2 years to 2 years 3 months while the other three calved at ages of 2 years 5 months, 2 years 8 months, and 2 years 9 months.

The data for the three weeks prior to and immediately following parturition were arbitrarily chosen for each animal. Because the measurements were taken on the same day each week, the last measurement before parturition fell 1 to 6 days before the day of parturition. It was desired to isolate the following sources of variation; between periods (P), i.e., before and after parturition; between animals (A); the interaction between periods and animals (PxA); between weeks within periods (W); and weeks within periods times animals or error (WA). Periods and weeks were regarded as fixed variables and animals as a random variable. A method presented by Schultz (1955) was employed to set up the model shown in table 1.

In the tests of significance, the between weeks within periods (W) and the

interaction between periods and animals (PxA) were tested against the error mean square. On the other hand, the mean square between periods was compared to PxA only. The degrees of freedom for this new error term was determined by the method of Satterthwaite (1946). In the statistical model used (table 1) the differences between animals were not of interest since no importance was attached to the magnitude of the measurements and therefore the statistical significance of the mean square between animals was not determined.

An interaction between periods and animals would indicate a differential response to the influence of parturition. To determine whether the interaction was caused by some factor peculiar to breed structure, an additional analysis was made. The measurements for 21 cattle were divided into 5 breed groups comprising (a) 3 Guernseys, (b) 2 Beef Shorthorn x Guernseys and 1 Red Poll, (c) 2 Brown Swiss, (d) 6 Jerseys and (e) 7 Holstein-Friesians. The interaction between periods and animals was subdivided into that between periods and breed groups and that between periods and cattle within breed groups.

TABLE 2

Results of analysis of variance for body measurements of heifers taken before and after first calving

	No. of Animals	Change at calving (Before—After) Mean (cm)	Significance[a]	Interaction (PxA) Significance[a]	Weeks within periods Significance[a]
Poll to muzzle	14	+0.05	n.s.	n.s.	n.s.
Head width	14	−0.02	n.s.	n.s.	n.s.
Eye to mandible[b]	11	−0.05	n.s.	n.s.	n.s.
Circum. of muzzle	14	+0.03	n.s.	n.s.	n.s.
Mandible to jaw[c]	14	+0.01	n.s.	n.s.	n.s.
Circum. of neck	21	−1.81	***	n.s.	n.s.
Heart girth	21	−3.84	***	**	n.s.
Withers height	21	+0.92	***	*	n.s.
Width of shoulders	21	−1.23	***	*	n.s.
Depth of chest	21	−0.91	***	n.s.	**
Length of body	21	−0.03	n.s.	**	n.s.
Circum. of metacarpus	21	−0.21	***	*	n.s.
Circum. of metatarsus	21	−0.24	**	**	n.s.
Stifle to stifle (tape)	21	+0.30	n.s.	n.s.	**
Width of hooks	21	−0.30	***	*	n.s.
Width of thurls	14	−0.05	n.s.	n.s.	n.s.
Width of pins	21	−0.26	n.s.	n.s.	n.s.
Hooks to pins	21	−0.14	n.s.	n.s.	n.s.
Body weight	20	−109.0 (lb)	***	***	***

[a]n.s.—not significant· *=P<0.05, **=P<0.01, ***=P<0.001.
[b]From top of eye socket to angle of mandible.
[c]From angle of mandible to anterior extremity.

RESULTS AND DISCUSSION

The head measurements were unaffected by parturition as indicated in table 2. The circumference of neck declined by an average of 1.81 cm and may be attributed to the dehydration of the body tissues incident to parturition and subsequent lactation. In as much as both circumference of neck and stifle to stifle distance are measurements of muscle developments this drain on the body may affect the stifle to stifle measurement also but be masked by the complicating effect of the udder swelling. This swelling of the udder becomes apparent in the stifle to stifle measurement one or two weeks before parturition and for a week or so afterwards. As anticipated, this measurement reached a maximum soon after

parturition and then declined. Because of this curvilinearity statistically significant differences were recorded between weeks within periods before and after parturition and the quadratic regression of measurements on weeks was significant at the 0.05 level of probability. The mean value before parturition was not significantly different from that after parturition.

A series of weekly changes similar to those of the stifle to stifle measurement, though not statistically significant, was also observed in the case of length of body (from the anteriormost cervical vertebra between the scapulae to the left tuber ischium or pin bone). In fact, most of the variation between weeks was accounted for by the quadratic regression of measurements on weeks. This might be associated with the relaxation of the pelvic bones at parturition since the left tuber ischium was a reference point. The length of body, however, showed no consistent change with parturition but the animals did exhibit highly significant differential responses. These differences might be apparent rather than real due both to a possible sagging of the back and to the difficulty with which the anterior reference point could be palpated.

The leg circumferences, both fore and rear, were less after parturition than before, the fore leg by 0.21 cm and the rear leg by 0.24 cm. This may be due to dehydration of the soft tissue or to improved lymphatic return similar to that observed after parturition in women. These leg measurements seemed to reach minimum values at 4 to 7 weeks after parturition.

Of the pelvic measurements, only the width between external points of tuber coxae (hooks) showed statistically significant sources of variation. This width declined by 0.30 cm at parturition but there was also a significant differential response which was small in comparison with the change at calving. The decline might be attributed to a return to normal after relaxation in preparation for parturition. Although the width of pins showed a decline it just failed to reach statistical significance ($P < 0.10$). There was some evidence, however, that the minimum value after parturition was not reached until about one month postpartum and it is possible that significant differences might have been obtained if data for 4 or 5 weeks postpartum had been analyzed. The width of thurls and length from hooks to pins (length of pelvis or rump) were unaffected by parturition.

In the shoulder region there were highly significant postpartum declines in heart girth, width of shoulders (the straight-line distance between the shoulder points measured by large calipers) and depth of chest. These declines were probably due to the physical effect of the weight of the calf. Similarly, the increase in the height at withers may be attributable to the removal of the calf and placental membranes whose combined weight would seem to depress the height at withers before parturition. In the case of width of shoulders, heart girth and height at withers, significant differential responses were recorded but the between-weeks-within-periods variation was significant only in the depth of chest measurement due to a rise of 0.50 cm in the week prior to parturition and to a marked fall of 0.50 cm in the third week thereafter. The quadratic regression of chest depth on weeks approached statistical significance. There changes may be due to relaxation in preparation for parturition and to tension of ligmanets thereafter, respectively.

For purposes of comparison body weights at each of the three weeks before and after parturition were analyzed also. The mean decline in weight was found to be 109.0 lb. The interaction between animals and periods was found to be highly significant indicating that the weight loss varied appreciably from animal to animal, an average increase of 16 pounds in weight was recorded in the second week prior to parturition and in the postpartum period the weight declined presumably due to the drain of lactation on the body reserves. These changes resulted in a statistically significant between-weeks-within-periods mean square. After adjusting for the change at parturition, the quadratic regression of weight

on weeks was significant ($P < 0.05$), due to a gradual increase in weight until parturition and a gradual decline afterward.

For those measures which showed statistically significant sources of variation the original data were converted into logarithms and analyzed with the results as indicated in table 3. The only changes compared with the original analysis concerned the interaction between animals and periods. That of the circumference of the rear leg (metatarsus) was now significant only at the 5 percent level of probability, while that of width of shoulders was not statistically significant. The interaction in the case of the stifle to stifle measurement became statistically significant at the 5 percent level of probability. It would seem, therefore, that the interaction between animals and periods was, in general, not caused by a correlation between the magnitude of the changes in the measures of the individual animals and the magnitude of the measures themselves.

TABLE 3

Results of analysis of variance of the logarithms of the body measurements of heifers taken before and after first parturition

	No. of animals	(as a % of magnitude before parturition)	Significance[a]	Interaction (PxA) Significance	Weeks within periods Significance
Circum. of neck	21	−2.18	***	n.s.	n.s.
Heart girth	21	−2.12	***	**	n.s.
Withers height	21	+0.77	***	*	n.s.
Width of shoulders	21	−2.95	***	n.s.	n.s.
Depth of chest	21	−1.44	***	n.s.	**
Length of body	21	−0.02	n.s.	**	n.s.
Circum. of metacarpus	21	−1.24	*	*	n.s.
Circum. of metatarsus	21	−1.24	***	*	n.s.
Stifle to stifle (tape)	21	+0.22	n.s.	*	**
Width of tuber coxae hooks	21	−0.63	***	*	n.s.
Width at tuber coxae pins	21	−0.85	n.s.	n.s.	n.s.
Weight	20	−10.45	***	***	***

[a]See footnote table 2.

Since the difference of two logarithms represents the division of one natural number by another, the difference of the means before and after parturition became the ratio of their measures after and before parturition when converted to antilogarithms. By subtracting one from this ratio and multiplying by 100, the result was the change at parturition expressed as a percentage of the measurement before parturition (table 3).

The circumferences of the legs and the depth of chest show percentage declines of 1.24 to 1.44 percent while heart girth and circumference of neck declined by about 2.1 percent. Width of shoulders showed the highest percentage decline (2.95%) of the body measurements whereas width of hooks showed the least (0.63%). Height at withers increased by 0.77 percent. As expected, body weight showed the largest decline of all, viz., 10.45 percent.

With regard to the interaction between periods and animals, it was only in the case of the stifle to stifle measurements that the interaction between periods and breed groups was significantly greater than that between periods and animals within breed groups. This significant interaction was largely attributable to most of the Jerseys showing a decline after parturition, the Holstein-Friesians showing no change and the other three groups showing increases. To what this differential

response was due could not be ascertained. From these results it can be concluded that, with this one exception, the interaction between periods and animals was not a breed difference but was due to individual differences between animals irrespective of breed.

These changes seemed to be largely independent of the inheritance of the individual. This is partly borne out by the absence of breed differences as indicated above. However, to test this in another way the interaction between periods and animals was divided into the interaction between periods and animals within twin-pairs and the residual interaction (i.e., the interaction of periods with twin-paired and single-born animals). If there are changes attributable to inheritance, then the differences of the changes within twin-pairs should be less than the differences of the changes between twin-pairs and singly-born animals. In only one instance was this so. For heart girth, the interaction within twin-pairs was significantly less ($P < 0.05$) than the residual interaction and in only two other cases did it approach statistical significance ($P < 0.10$). These were stifle to stifle and width of shoulders. This is interpreted as indicating that members of a twin pair at parturition tend to have declines in heart girth, and possibly stifle to stifle and width of shoulders, of a closer magnitude than one would expect from pairs of animals taken at random. With these possible exceptions it would appear that the inheritance of the animal plays a negligible role in influencing these changes and so these results are applicable to cattle in general. These results may serve as an indication of the type of change likely to occur at later parturitions although the magnitude of these changes may be different.

In the literature the only paper that could be found to give any details regarding changes in body measurements at parturition was that of Crichton and Aitken (1954). Their paper dealt with comparisons of monozygotic twins on high and low planes of nutrition during rearing through first lactation. As in the present study, they found declines in heart girth at first parturition with the possible exception of low plane animals. With regard to width of hooks (hips) figures 2 and 3 in their paper showed little or no change. Height at withers of 3 out of 4 groups showed a decline and only one group (the low-low group) showed an increase with parturition. With the exception of the latter group, these results are in conflict with those of the present study. Crichton and Aitken suggested that the temporary reduction in the height at withers of the high plane animals might be due not to differences in bone development but to drawing on muscle or fat deposited over the shoulders. If this were so, it might mean that the naimals in the present study were comparable to the low plane animals. However, the animals in the present study were raised on a normal to above normal plane of nutrition and so the plane of nutrition would seem not to be the cause of the similarity. It must be appreciated that the data of Crichton and Aitken are less reliable than those of the present study since they are based on averages of 2 or 4 animals.

SUMMARY

The changes in body measurements of heifers at first parturition have been studied. The magnitude of the changes was calculated from the difference of the means before and after parturition and the analysis of variance technique was employed to test the statistical significance of these changes.

Height at withers showed a significant increase of 0.92 cm (or 0.77%) after parturition. Measurements showing significant declines were: circumference of fore leg (0.21 cm or 1.27%), circumference of rear leg (0.24 cm or 1.24%), circumference of neck (1.81 cm or 2.18%), heart girth (3.84 cm or 2.12%), width of shoulders (1.23 cm or 2.95%), depth of chest (0.91 cm or 1.44%), width of hooks (0.30 cm or 0.63%), and body weight (109.0 lb or 10.45%). The other 10 measures showed no statistically significant changes.

Possible explanations of these changes are discussed. Individual variations were encountered but these were independent of the inheritance of the individual as heredity was found to play a very minor role in influencing these changes.

ACKNOWLEDGMENTS

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REFERENCES

Crichton, J. A. and **J. N. Aitken.** 1954. The economical rearing of dairy heifers. Proc. Nutrition Soc. 13: 10–16.

Satterthwaite, F. E. 1946. An approximate distribution of estimates of variance components. Biometrics 2: 110–114.

Schultz, E. F., Jr. 1955. Rules of thumb for determining expectations of mean squares in analysis of variance. Biometrics 11: 123–148.

SOIL MOISTURE INVESTIGATIONS AT *NEOTOMA*, A FOREST BIOCLIMATIC LABORATORY IN CENTRAL OHIO[1]

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One of the many items of ecological import studied at the *Neotoma* bioclimatic laboratory during the past several years has been the soil moisture relations of opposing slope and ridge top forests and open valley habitats. Since the vegetation of *Neotoma*, as well as the specific sites presently being investigated, has previously been reported (Wolfe et al., 1949; and Wolfe and Gilbert, 1956), the following brief descriptions of the vegetation dominating the habitats in which soil moisture studies have been conducted appear sufficient for the purpose of this paper.

Lower northeast facing slope (*station #1, fig. 1*).—The vegetation of this habitat is a relatively young mixed mesophytic forest (undisturbed at the time of this writing for a minimum of 35 years) with a distinct shrub layer and luxuriant groundcover. The canopy is dominated by a variety of species including Beech (*Fagus grandifolia*[2]), Tuliptree (*Liriodendron tulipifera*), Red Maple (*Acer rubrum*), White Oak (*Quercus alba*), Red Oak (*Q. rubra*), Chestnut Oak (*Q. prinus*), Sugar Maple (*A. saccharinum*), White Ash (*Fraxinus americana*), and Black Cherry (*Prunus serotina*), among others.

Southwest facing slope (*station #3*).—The vegetation of this slope was originally dominated by Oak and Chestnut. With the death of Chestnut and subsequent lumbering there has developed on this site a secondary forest of mixed oak and hickory, also undisturbed for a minimum of 35 years. Dominant canopy species include Chestnut Oak, Black Oak (*Q. velutina*), White Oak, Scarlet Oak (*Q. coccinea*), Sweet Pignut Hickory (*Carya ovalis*), and Pignut Hickory (*C. glabra*).

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[2]Nomenclature essentially that of Gray's Manual of Botany, 8th edition (Fernald 1950).

The shrub layer is poorly developed and is underlain by a depauperate groundcover and a soil surface approximately 50 percent devoid of leaf litter.

Open valley.—The vegetation of the narrow valley of *Neotoma* was destroyed many years ago, and with subsequent pasturing there has developed the present treeless community dominated by Blue Grass (*Poa pratensis*), Asters (*Aster* spp.), Goldenrods (*Solidago* spp.), and, in slight depressions, Rushes (*Juncus* spp.). A number of common Ohio weeds frequently occur throughout the community. Pasturing was terminated one year prior to these investigations.

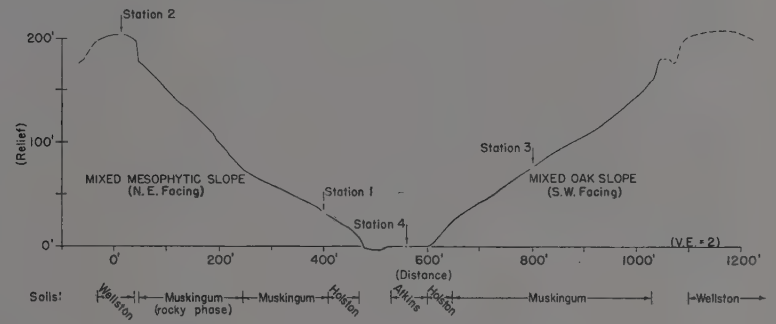


FIGURE 1. Cross section of *Neotoma* valley showing location of bioclimatic stations and distribution of major soil types.

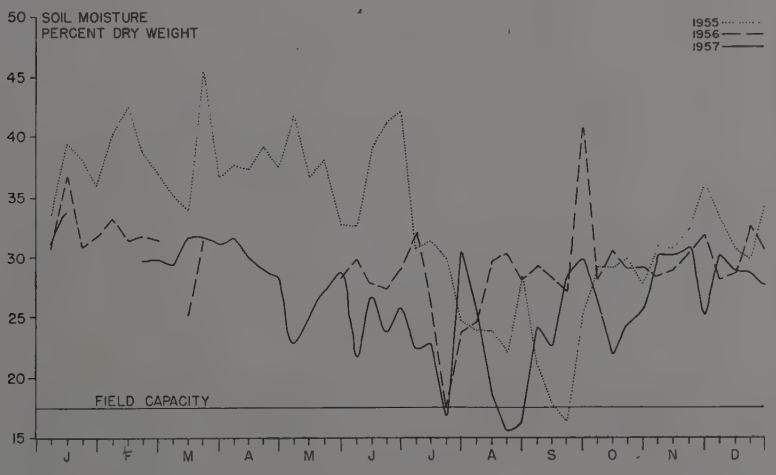


FIGURE 2. Annual soil moisture regimens of the one to three inch depth of Atkins Silt Loam of valley bottom (station #4).

Western ridge top (station #2).—A relatively open forest community of Chestnut Oak, with Black Oak as a common associate, dominates the narrow western ridge top of *Neotoma* where a major part of the present bioclimatic studies is being conducted. However, since soil moisture studies at this site at the time of this writing have been underway for only a few months, a discussion of the moisture relations of this habitat must necessarily come at a later date.

Classification of *Neotoma* Soils

The major soil types transecting the central portion of *Neotoma* valley, where present bioclimatic studies are being emphasized, are as follows (fig. 1).

Wellston silt loam. A brown, acid, permeable, well-drained soil dominating opposing ridge tops, and believed developed from approximately two ft of loess material overlying an even-textured sandstone bedrock. The general profile and certain horizon characteristics at station #2 are as follows:

Ao. A relatively thick and evenly distributed layer of leaves, largely of Chestnut Oak.

Ao_1. One-fourth to one-half in. in thickness.

Ao_2. A matted complex of roots and well-decayed organic matter ranging from one-half to one and one-half in. in thickness, frequently light gray to near white due to leaching and abundant fungal filaments.

A_2. A pale brown silt loam approximately five in. in thickness and gradually grading into B_1 horizon.

B_1. A yellow-brown fine silt loam approximately six to seven in. in thickness.

B_2. A dark yellow-brown coarse silty clay loam nine to ten in. in thickness, and underlain by a solid floor of even-textured brown sandstone.

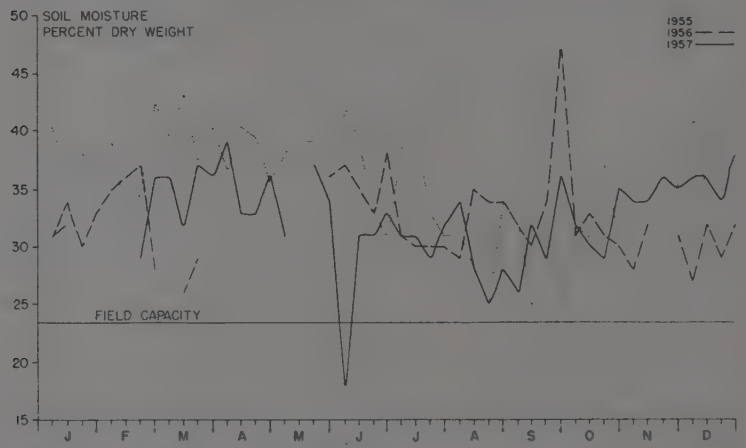


Figure 3. Annual soil moisture regimens of the six to nine inch depth of Atkins Silt Loam of valley bottom (station #4).

The profile is well penetrated with roots ranging from less than one mm to approximately five cm in diameter, many extending to and distributed horizontally upon the sandstone bedrock. Underground stems of *Smilax rotundifolia* are also common throughout most of the profile.

Muskingum fine sandy loam. The most prevalent soil type of *Neotoma*, dominating most of the opposing slopes and with the following specific profile characteristics at bioclimatic stations #1 and #3.

Station #1, mixed mesophytic forest.

Ao. Well developed and generally distributed leaf litter.

A_1. Zero to five in. Dark, near black, fine sandy loam with numerous fine roots in upper part. Lower two in. with abundant rock fragments of pebble size.

A_2. Five to 12 in. Pale brown fine sandy loam with many roots.

B_1. Twelve to 20 in. Yellow-brown loam with many roots.

B_2. Twenty to 36 in. Dark yellow-brown loam with few roots, and underlain by mottled silty material.

Station #3, mixed oak forest.

Ao. Zero to one-half in. Dark, near black, morlike organic layer.

A_1. One-half to two in. Dark, near black, sandy loam high in organic matter with many fine roots.

A_2. Two to 14 in. Pale yellow-brown loam with abundant roots.

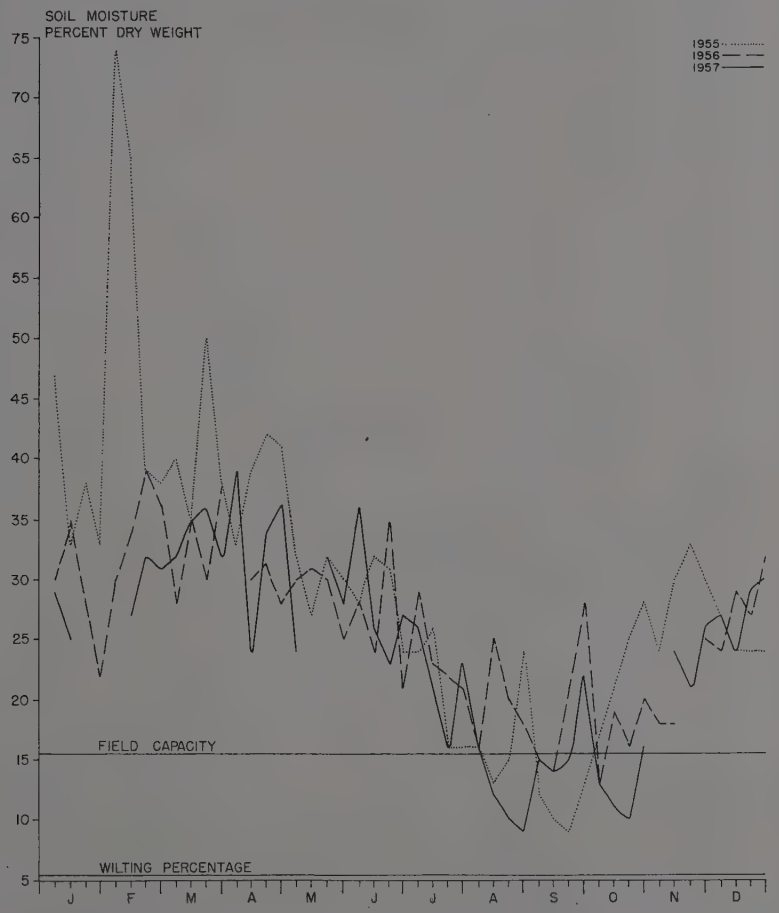


FIGURE 4. Annual soil moisture regimens of the one to three inch depth of Muskingum Silt Loam underlying mixed mesophytic forest at station #1.

B. Fourteen to 28 in. Dark brown loam with many rock fragments and few roots.

C. Sandstone bedrock, frequently fragmented.

Muskingum sandy loam (rocky phase).—Much the same as Muskingum Fine Sandy Loam, but with extreme rockyness near the surface. Most prevalent on the upper relatively steep north-east facing talus slope.

Holston silt loam.—A yellow-brown, moderately heavy, acid terrace soil de-

veloped from laminated silt and clays believed deposited during ponding resulting from damming of local drainage by Illinoian glacial outwash. Occurs sporadically along lower elevations of both slopes.

Atkins silt loam.—A relatively complex soil derived from stratified alluvium and occurring in the poorly drained valley bottom. Profile characteristics of this soil at one site are as follows:

Horizon 1. Sod, from zero to three-fourths in. A matted complex largely composed of stems and roots of Blue Grass, Asters, and Goldenrods.

Horizon 2. A fine silt loam occurring from the above and varying in thickness to a depth of approximately two in. An evenly dark brown soil some

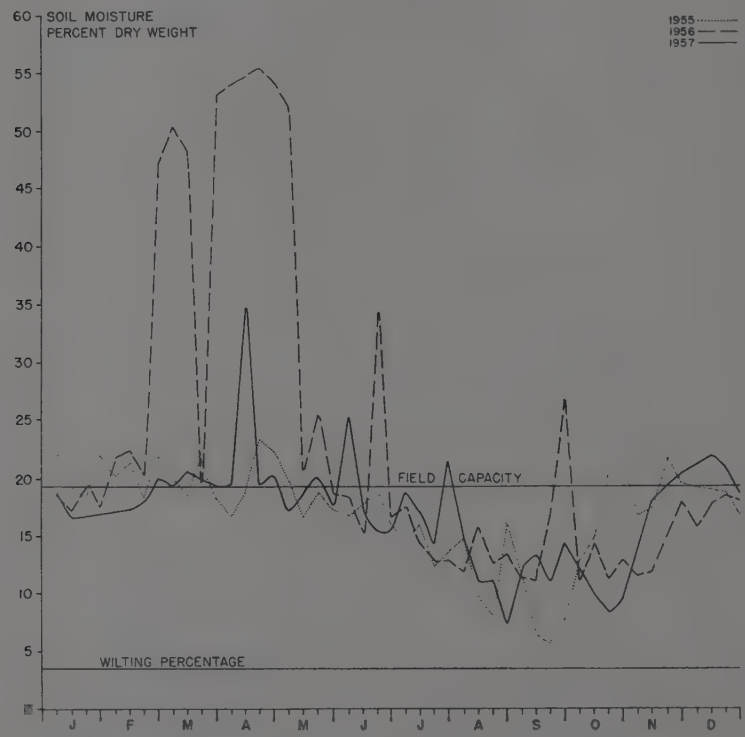


FIGURE 5. Annual soil moisture regimens of the six to nine inch depth of Muskingum Silt Loam underlying mixed mesophytic forest at station #1.

one in. in thickness and abundantly penetrated by roots with maximum diameters of approximately one mm.

Horizon 3. A silt loam occurring from the above to a depth usually varying from five to six in. Color is dark brown with occasional gray areas and abundant rust-brown mottling. Horizon is well penetrated by fine roots.

Horizon 4. A coarse clay occurring from the above to a depth usually varying from 11 to 14 in. Color is dark blue-gray with occasional rust-brown mottling especially along root channels. Horizon is well penetrated with fine roots, and with occasional roots of approximately one mm diameter.

Horizon 5. A light gray loam occurring from above to a depth of approximately 20 in. and with occasional rust-brown mottling. Roots rare.

Horizon 6. A gray coarse clay loam occurring from above to a depth varying from 26 to 29 in., and with abundant rust-brown mottling. Roots rare.

Horizon 7. A pale brown coarse sand occurring from above to an unknown depth and with occasional gray streaking and orange mottling. Roots absent.

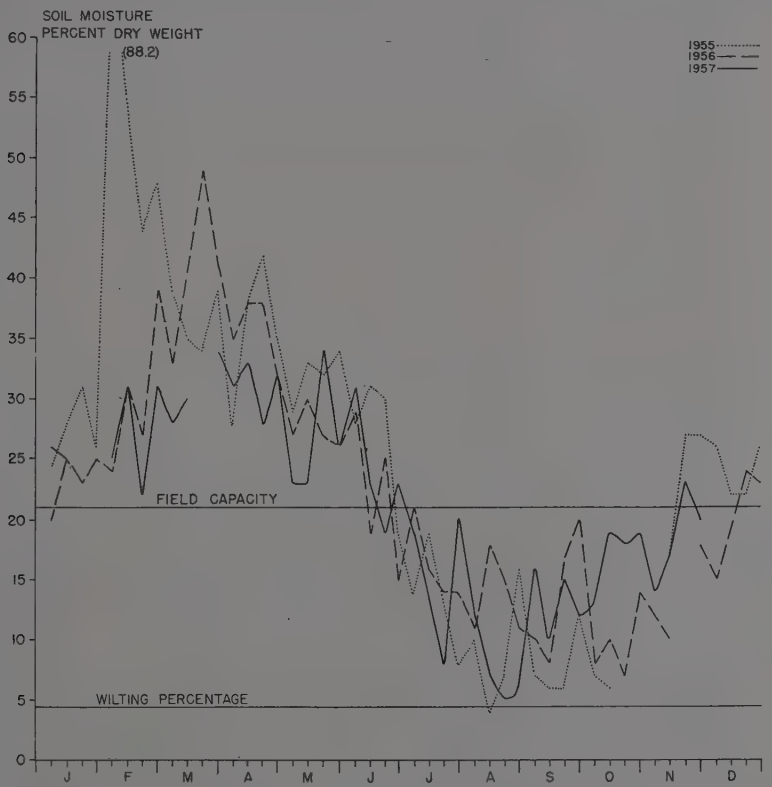


FIGURE 6. Annual soil moisture regimens of the one to three inch depth of Muskingum Silt Loam underlying mixed oak forest at station #3.

SOIL MOISTURE STUDIES

Weekly, occasionally twice weekly, soil moisture sampling was initiated in November, 1954, a minimum of three and a maximum of five random samples being collected at both one to three and six to nine in. depths within the mixed mesophytic and mixed oak transects (station #1 and #3) as well as the valley bottom (station #4).

Individual samples were obtained by a soil tube, usually weighed between 150 and 200 gm, and were dried for a minimum of three days at 105° C. Both plant and pressure membrane tests were utilized in obtaining permanent wilting percentage data; however, since resultant averages were much the same, results of the pressure membrane tests (15 atm) were chosen to represent wilting percentage. Approximate field capacity values of the same soils and depths were obtained by

determining moisture retention of samples subjected to a tension of one-third atm. Results of the membrane tests are included in table 1.

Annual patterns of soil moisture on a weekly, occasionally twice weekly, basis for the one to three and six to nine in. levels of the Muskingum Fine Sandy Loam of the sites investigated (stations #1 and #3) and the Atkins Silt Loam of the valley bottom have thus been obtained for the years 1954 to, and including, 1957 and are graphically presented in figures 2 to 7.

TABLE 1

Permanent wilting and field capacity percentages of certain Neotoma *soils as derived by pressure membrane tests*

Type and Location	Depth(in.)	Perm. Wilt.	Field Cap.
Muskingum F. S. Loam			
1. Mixed Oak Slope	1–3	4.5	21.0
(Station #3)	6–9	3.0	18.9
2. Mixed Meso. Slope	1–3	5.5	15.5
(Station #1)	6–9	3.6	19.4
Atkins Silt Loam	1–3	8.4	17.5
(Station #4)	6–9	13.3	23.6

Atkins Silt Loam of Valley Bottom

The major control of soil moisture of this habitat throughout most, frequently all, of the year is an elevated water table which usually occurs at a depth ranging from a few inches to approximately three ft from the soil surface. The near presence of such a saturated soil condition results in soil moisture values usually well above corresponding field capacity values throughout the year (fig. 2 and 3). However, during late summers characterized by relatively little rainfall, lowering of the water table may be sufficient to result in occasional soil moisture values of the sampled levels slightly less than field capacity. However, it appears that during most years rainfall frequency and amount is sufficient to maintain above field capacity values throughout most of the summer, and a drouth of considerable degree would be necessary to reduce soil moisture values to permanent wilting levels.

Muskingum Silt Loam of Mixed Mesophytic Slope at Station #1

1. One to three in. level. With the return of relatively frequent rainfall, usually during October, soil moisture of this layer rapidly increases to and beyond the corresponding field capacity and remains well above this level during the following fall, winter, and spring months (fig. 4). In late May or early June a general decrease in soil moisture usually commences, culminating in minimum values which are usually attained during late August or September. However, these minimum values are well above the permanent wilting percentage and, consequently, little precipitation is required to return the moisture of this level to and above the field capacity level.

2. Six to nine in. level. Weekly soil moisture values of this layer usually increase rapidly during late October or November to field capacity levels and generally remain at this level until the latter part of May or the middle of June, depending upon the amount and distribution of winter precipitation (fig. 5). At this time a marked decrease in weekly soil moisture values begins and usually continues until the latter part of August and September at which time minimum values for this level for the three years here reported were well above the corresponding permanent wilting percentage, indicating an ample plant supply of soil moisture. With the reoccurrence of relatively frequent rainfall, usually during the latter

part of September and October, soil moisture values rapidly return to or near field capacity values.

Muskingum Silt Loam of Mixed Oak Slope at Station #3

1. One to three in. level. With the return of relatively frequent rainfall during October and early November, soil moisture values of this level rapidly increase and by mid or late November have usually not only attained but surpassed corresponding field capacity, and usually remain well above this level until early summer of the following year (fig. 6). A general decrease in weekly soil moisture values of this level usually initiates during mid or late April and by late June or early July has resulted in a reduction of soil moisture to field capacity values. Drying of this soil continues and yearly minimum or near minimum values are usually first attained in mid August, usually being at or within several percentage units above permanent wilting percentage. During most summers

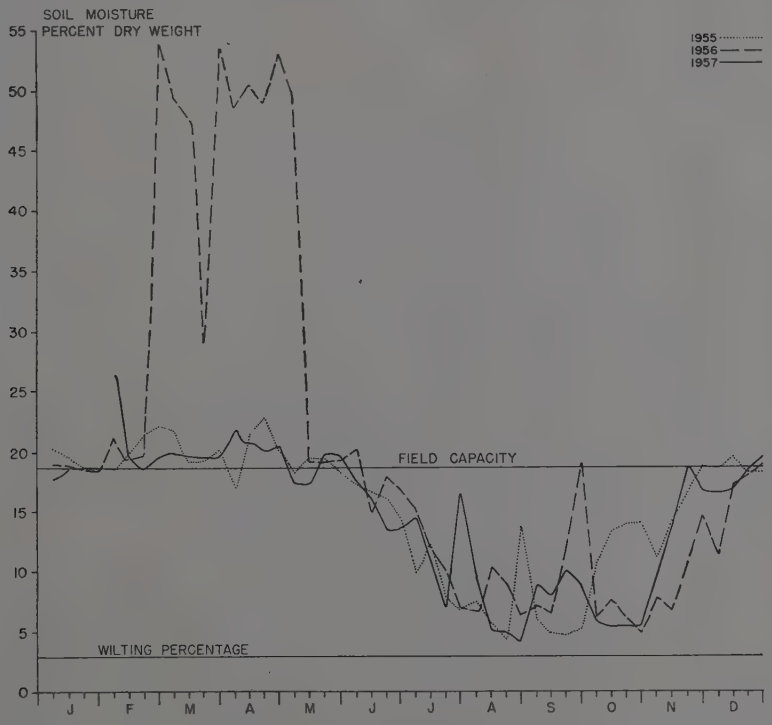


FIGURE 7. Annual soil moisture regimens of the six to nine inch depth of Muskingum Silt Loam underlying mixed oak forest at station #3.

thundershower activity results in at least one marked soil moisture recovery, usually lasting for a period of one week to ten days. A marked increase in weekly soil moisture of this level usually begins by the first or middle of September, and by the first of December soil moisture values usually approximate or exceed field capacity.

2. Six to nine in. level. The reoccurrence of relatively frequent rainfall during October and November results in a relatively rapid increase in soil moisture at this level and field capacity values are usually attained by early December (fig.

7). Weekly soil moisture values then generally remain at this level until approximately the first of May at which time a marked and consistent decrease in weekly soil moisture begins and continues until the latter part of August and September, at which time minimum values, usually several units above corresponding wilting percentage, occur. A relatively rapid increase in soil moisture of this level then generally occurs early in October.

During years characterized by relatively great amounts of precipitation occurring in late winter and spring months, such as 1956, the soil moisture content of the entire profile of both slope soils is considerably above field capacity due to the relatively great amount of downslope seepage and impenetrability of the underlying bedrock. However, this relatively high moisture content rapidly decreases during the latter part of the spring season due to a complex of factors which includes (1) closing of the forest canopies and a corresponding marked increase in rainfall interception, (2) marked increase in atmospheric vapor pressure deficits of lower forest air levels, and (3) rapid increase in removal of soil water by increased transpiration rates.

SUMMARY

1. General profile descriptions of the soils occurring on the opposing slopes, ridge top, and valley bottom sites of *Neotoma* where present ecological investigations are being conducted are here presented.

2. Yearly soil moisture regimens of the one to three and six to nine in. levels of the above sites are graphically presented and generally described.

3. The major control of soil moisture of the open valley habitat is an elevated water table which results in soil moisture values considerably above field capacity throughout most, or all, of the year.

4. Soil moisture values of the south-east facing slope, dominated by a young mixed oak forest, are at or above field capacity throughout the winter and spring periods. A marked decrease in soil moisture usually begins during early summer and generally continues until late August or September, at which time minimum values either at, or extremely near, wilting percentage are attained.

5. Soil moisture values of the north-east facing slope, dominated by a young mixed mesophytic forest, are at or above field capacity throughout the winter and spring periods. A rapid decrease in soil moisture here also begins during early summer and similarly continues until late August or September, at which time minimum values are attained. However, these minimum values are significantly above corresponding permanent wilting percentages.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to The Ohio State University Advisory Committee on Research Grants, the United States Atomic Energy Commission, and the Ohio Agricultural Experiment Station who have been the major sponsors of this research. Sincere appreciation is also expressed to Dr. Nicholas Holowaychuck and Mr. Harlan R. Finney, Department of Agronomy, The Ohio State University, for their field and laboratory assistance in the classification of *Neotoma* soils. Dr. Edward S. Thomas and Mr. John Freeman have graciously permitted the continued use of their land. Our own department has contributed much in the way of equipment and expendable materials necessary in such research, and the Service Department of The Ohio State University has continued to supply necessary transportation for haulage of heavy materials to the research area.

LITERATURE CITED

Wolfe, J. N., R. T. Wareham, and **H. T. Scofield.** 1949. Microclimates and macroclimate of Neotoma, a small valley in central Ohio. Ohio Biol. Surv. Bull. 41. 8: 1–267.

Wolfe, J. N. and **G. E. Gilbert.** 1956. A bioclimatic laboratory in southern Ohio. Ohio Jour. Sci. 56: 107–120.

A NEW SUBSPECIES OF *TYPOCERUS BRUNNICORNIS* LE CONTE

(COLEOPTERA: CERAMBYCIDAE)

JOSEF N. KNULL

Department of Zoology and Entomology, The Ohio State University, Columbus 10

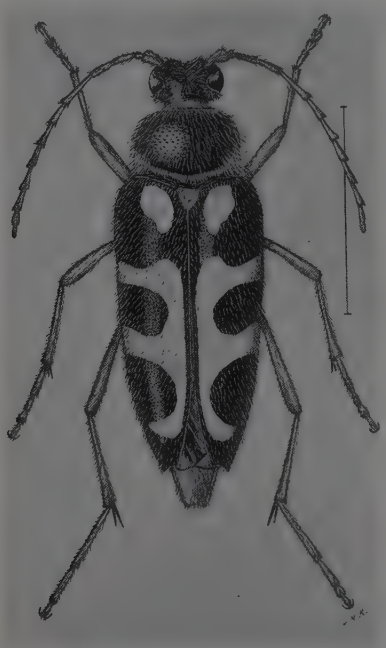
The following form differs enough from the type of *Typocerus brunnicornis* Lec. to warrant a name.

Typocerus brunnicornis inflatus n. subsp.

This subspecies differs by having pronotum more inflated in front of middle, surface more sparsely and lightly punctured.

Length 10 mm; width 3.2 mm.

Male holotype labeled Southern Pines, N. C., May 20, 1916, A. H. Manee, collector in H. W. Wenzel Collection, Ohio State University.



Typocerus brunnicornis inflatus n. subsp. ♀, (Line represents 5 mm).

Allotype and paratypes from same locality, June 7, 1952 and June 13, 1953, H. and A. Howden, collectors, from flowers of *Ceanothus americanus* L. Allotype and paratypes in collection of Dr. H. F. Howden, to whom I am indebted for loan of material. One paratype in Canadian National Collection and one in collection of author.

I am indebted to Dr. P. J. Darlington, Jr. for comparing specimens with the LeConte type of *T. brunnicornis*.

BURIED SOILS OF GLOBE HILL, UPPER OHIO VALLEY

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A terrace, 5 mi downstream from Wellsville, Ohio, standing about 200 ft above the Ohio River, was recently excavated for the construction of a new highway, exposing several different layers of soil which record a part of the history of the Pleistocene Epoch. It is located about one mi south of Moscow and two and one-half mi north of New Cumberland, Clay Township, Hancock County, West Virginia. (Wellsville, Ohio, W. Va., Pa., quadrangle map of the U. S. Geological Survey). The site of the excavation is near the Globe Hill archeological site (Mayer-Oakes, 1955, p. 132) and this report will refer to the terrace as Globe Hill because its surface is dissected and in part hilly and in part sloping.

The region near Globe Hill has an upland surface which is a part of the unglaciated Allegheny Plateau. The ridgetop remnants of the dissected surface have a general elevation of about 1240 ft. Several terraces at general levels of 1020 to 960 ft, 850 to 800 ft, 760 to 740 ft and 720 to 680 ft elevation are developed near the river. The Ohio River, here at about 650 ft elevation, has a very narrow flood plain. The river flows over a bed of sand and gravel, about 45 ft thick, and the rock floor of the Ohio Valley is at 602 ft elevation.

PREVIOUS WORK

The terraces in the Upper Ohio Valley have been mentioned by Leverett (1902, pp. 88–98, pp. 121–125; 1929, p. 229; 1934, pp. 101–102), Stout and Lamb (1938, pp. 68–70), Stout (1953, pp. 183–189), Hubbard (1954, pp. 365–370) and Ireland (1940, 1943). However, no detailed investigation has yet been made using modern methods of pedology, of stratigraphy, or of morphology as determined from air photos or from really detailed topographic maps. The study of the soils of varying development shows the terraces are of varying ages and it is hoped will lead to similar pedologic observations elsewhere. It is hoped that these will eventually contribute, along with other required detailed studies, to an elucidation of the Pleistocene history of the Upper Ohio Valley.

TOPOGRAPHY OF GLOBE HILL

Globe Hill was formerly a nearly level to gently sloping surface as is evidenced by the horizontal layers of sand and gravel underlying it. This surface has been strongly dissected by small tributaries of the Ohio River to a series of ravines and sloping interfluvs at 838 to 820 ft elevation, and in part a sloping terrace whose outer escarpment stands at 855 ft elevation. The edge of this escarpment is 205 ft above the river.

THE SOILS AND BURIED PALEOSOLS OF GLOBE HILL

The surface soil of Globe Hill is a 2 in. thick layer of black silt loam containing a few fragments of angular sandstone and pebbles of igneous rocks. Where this surface and underlying material have been gullied, a pavement of these stones litters the sides and bottoms of the gullies. Part of Globe Hill contains an Indian mound built of Unio shells.

Beneath the surface soil, a layer of silty material occurs at most places, which lacks pebbles, coarse sand and is not layered or bedded as alluvial soils are. It ranges from a few feet to several feet thick as at site WV 1. It may be wind deposited material.

The silt is lacking at a few places. It is underlaid, at Site WV–1, by the paleosol of Gravel I and at Site WV–3, by the paleosol of Gravel II and a paleosol of the Sandy Alluvium. The soil profile descriptive terminology used below follows usage of the U. S. Dept. Agriculture, Soil Survey Manual, Handbook 18, 1951, except that a Roman numeral is added to designate a paleosol.

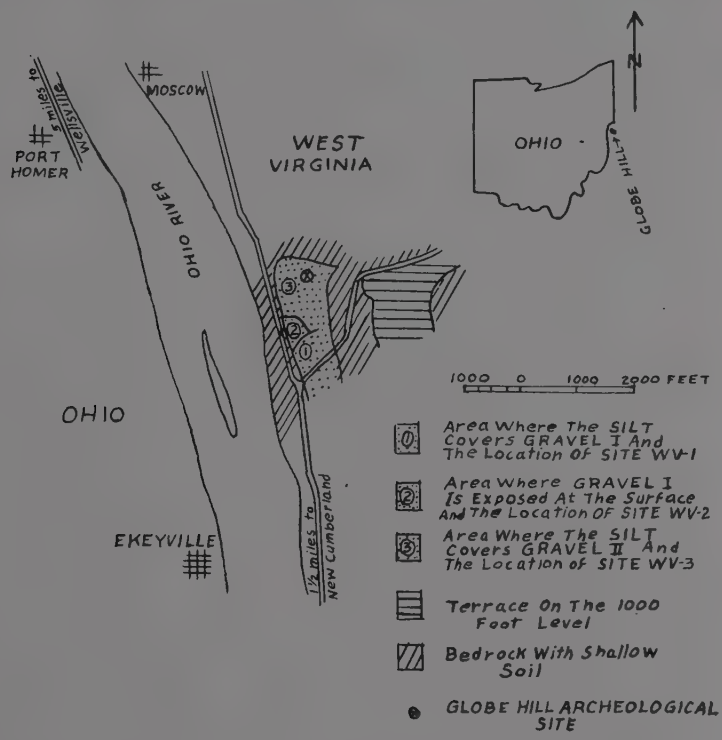
MOSCOW
PORT HOMER
WEST VIRGINIA
OHIO RIVER
OHIO
EKEYVILLE
1½ miles to New Cumberland
N
OHIO
GLOBE HILL
1000 0 1000 2000 FEET
Area Where The SILT Covers GRAVEL I And The Location Of SITE WV-1
Area Where GRAVEL I Is Exposed At The Surface And The Location OF SITE WV-2
Area Where The SILT Covers GRAVEL II And The Location of SITE WV-3
Terrace On The 1000 Foot Level
Bedrock With Shallow Soil
GLOBE HILL ARCHEOLOGICAL SITE

FIGURE 1. Surface map of Globe Hill.

Soil and Paleosol at Site WV–1

Location, 820 ft north of junction of new highway and dirt road, 2½ mi north of New Cumberland, W. Va.; slope 8%, convex, at crest of interfluv; 838 ft elevation; dissected terrace; well drained.

Depth and Horizon	Profile Description (moist colors in Munsel notations, moist consistence).
0–1 in. A_{11}	Black N 2/0 silt loam; moderate very fine granular structure; extremely acid, pH 4.4; friable; very few pebbles of crystalline rocks and channers of sandstone; colluvium from upper slopes.
1–2 in. A_{12}	Very dark gray 2.5yr 3/1 silt loam; massive in place, breaking to weak fine granular peds; very strongly acid, pH 4.6; firm in position; pebbles as in A_{11}; colluvium from upper slopes.

2–9 in. A_2	Dark grayish brown 10yr 4/2 coarse silt loam; weak medium platy structure; very strongly acid, pH 4.6; very friable; pebbles and coarse sand absent; weathered Silt (wind deposited).
9–12 in. B_1	Yellowish brown 10yr 5/4 coarse silt loam; weak fine subangular blocky structure; very strongly acid, pH 4.6; friable; pebbles and coarse sand absent; weathered Very Fine Sand.
12–35 in. B_{21}	Dark yellowish brown 8.75yr 4/4 fine silt loam faintly mottled in lower part yellowish brown 10yr 5/4; moderate medium subangular blocky structure; very strongly acid, pH 5.0; friable, firm in position; pebbles and coarse sand absent; weathered Silt.
35–43 in. B_{22}	Strong brown 8.75yr 5/8 silt loam distinctly mottled reddish brown 6.25 yr 4/4; strong medium subangular blocky structure, thin light yellowish brown 1.25yr 6/3 ped faces; strongly acid, pH 5.2; firm; pebbles and coarse sand absent weathered Silt.
43–54 in. B_{31m}	Brown 7.5yr 4/4 silt loam prominently mottled light brownish gray 2.5yr 6/2; fragipan with strong very coarse prismatic structure breaking to strong medium subangular blocky peds, light brownish gray 2.5yr 6/2 loamy ped faces 3 mm thick; very strongly acid, pH 4.8; firm; pebbles and coarse sand absent; leached Silt.
54–78 in. B_{32}	Mottled brown 8.75yr 4/4 and light yellowish brown 1.25yr 6/4 silt loam; weak coarse subangular blocky structure, light yellowish brown 1.25yr 6/4 loamy ped faces 3 mm thick; very strongly acid, pH 4.8; friable; pebbles and coarse sand absent; upper part is leached Silt, lower part possibly includes a IA_b horizon of buried paleosol I.
78–90 in. IB_{2b}	Dark brown 10yr 4/3 gravelly silty clay loam faintly mottled pale brown 10yr 6/3 and with prominent black Mn stains; moderate medium angular blocky structure, thin yellowish brown 10yr 5/4 clay skins; firm; strongly acid, pH 5.4; pebbles 50% of soil mass, rotted so that only chert and quartz remain intact, forms of other pebbles form silty clay loam when rubbed; deeply weathered B_2 horizon of paleosol formed from Gravel I.
90–114 in. IB_{3b}	Distinctly mottled strong brown 7.5yr 5/8 and light brownish gray 10yr 6/2 gritty clay loam; structure not determined, sampled with bucket auger; acid, pH 5.8; friable when disturbed; pebbles 50% of soil mass, weathered strongly but not as much as in horizon IB_{2b}; paleosol formed from Gravel I.
114–168 in. IC_{1b}	Dark yellowish brown 10yr 4/4 gravel; acid, pH 5.8; noncoherent; pebble count, 630 pieces: sandstone and siltstone most pieces weathered 42%, hard quartz pebbles 11%, quartzite slightly weathered 10%, granite soft and weathered 6%, chert hard 31%; weathered Gravel I.
168 in. D	Sandstone bedrock.

The buried paleosol of Site WV–1 is formed from glacial outwash because crystalline rocks are not residual in the Upper Ohio Valley.

Soil and Paleosol at Site WV–2

Location, 920 ft north of junction of new highway and dirt road, 2½ mi north of New Cumberland, W. Va.; slope 8%, convex, 100 ft from crest of interfluv, 832 ft elevation; well drained.

Depth and Horizon	Profile Description (moist colors in Munsel notations, moist consistence).
0–1 in. A_1	Black N 2/0 silt loam; moderate very fine crumb structure; extremely acid, pH 4.4; very friable; few pebbles.

1–9 in. A_2	Brown 10yr 4/3 silt loam; moderate fine granular structure; extremely acid, pH 4.4; friable; pebbles absent; possibly a thin layer of wind deposited soil.
9–28 in. B_1	Dark brown 8.75yr 4/4 silt loam with few Mn stains; strong medium subangular blocky structure, dark brown 7.5yr 4/4 ped faces; very strongly acid, pH 4.8; friable; few deeply weathered pebbles; weathered Gravel I.
28–43 in. B_{21}	Strong brown 7.5yr 4/6 fine silt loam, coarsely mottled with few light yellowish brown 10yr 6/4 stains; strong coarse subangular blocky structure, dark yellowish brown 10yr 4/6 ped faces; strongly acid, pH 5.2; firm; many rotted pebbles; weathered Gravel I.
43–48 in. B_{22}	Reddish brown 5yr 4/4 sandy clay loam with frequent black Mn stains; strong coarse subangular blocky structure, dark brown 6.25yr 4/4 thin clay skins on ped faces; strongly acid, pH 5.4; firm; deeply weathered pebbles 30% of soil mass; weathered Gravel I.
48–63 in. B_{23}	Strong brown 7.5yr 4/8 gravelly clay loam with frequent coarse Mn stains; strong medium subangular blocky structure; strongly acid, pH 5.4; friable; pebbles and cobbles weathered so that granites are rotted, 50% of soil mass; weathered Gravel I.
63–74 in. B_{3cn}	Black N 2/0 gravel with little coarse sand; massive structure, weakly cemented with Mn when moist, strongly cemented when exposed and dry; strongly acid; pH 5.2; pebbles entirely coated with Mn stain, 85% of soil mass; Gravel I.
74–91 C_1	Dark brown 7.5yr 4/4 gravelly sandy loam mottled with dark reddish brown 5yr 3/4 and yellowish brown 10yr 5/4; massive structure; acid, pH 5.6; very friable; pebbles coated with clay 75% of soil mass; pebble count similar to horizon IC_{1b} of Site WV–1; Gravel I; rests unconformably partly on horizon D_1 and partly on horizon D_2 (fig. 2).
91 in. + D_2	Gray sandstone bedrock.
and	
91–92 in. D_2 or IA_{1b}	Black silt loam with fossil organic matter on buried surface; buried paleosol formed from Gravel II.
92–100 in. IA_{2b}	Grayish brown loam; few small pebbles; buried paleosol formed from Gravel II.
100–124 in. IB_b	Yellowish brown loam; few small pebbles; buried paleosol formed from Gravel II.

This buried paleosol was removed by excavating machinery before a more detailed soil description could be made. Its buried surface was steeply sloping and it butted against sandstone bedrock beneath the C_1 horizon.

Soil and Paleosols at Site WV–3

Location, 1800 ft north of junction of new highway and dirt road, 2½ mi north of New Cumberland, W. Va.; slope 10%, convex, on crest of sloping interfluv; 820 ft elevation; well drained.

Depth and Horizon	Profile Description (moist colors in Munsel notations, moist consistence).
0–27 in.	Colluvial A_1 horizon underlain by soil of the Silt, similar to those horizons described at Site WV–1.
27–34 in. IA_b	Coarsely mottled yellowish brown 10yr 5/4 and strong brown 8.75yr 5/6 fine silt loam with few large black Mn stains; strong medium angular blocky structure, pale brown 1.25yr 6/3 ped faces; strongly acid, pH 5.2; firm; pebbles 10%, rotted so that only quartz and chert remain; buried paleosol formed from Gravel II.

34–52 in. IB_{2mb} — Faintly mottled yellowish brown 10yr 5/4 and light yellowish brown 10yr 6/4 silty clay loam with large coarse Mn stains; fragipan with strong very coarse angular blocky structure garding to strong very coarse prismatic in lower part; thin red 3.75yr 5/8 silty clay skins in upper part and dark gray 10yr 4/1 vertical silty clay faces 3 mm thick in lower part; strongly acid, pH 5.2; very firm; pebbles 10%, rotted except those of quartz and chert; buried paleosol formed from Gravel II.

52–63 in. IB_{31mb} — Strong brown 7.5yr 5/6 loam coarsely mottled gray 10yr 6/1 and grayish brown 10yr 5/2; fragipan with moderate very coarse prismatic structure, reddish brown 6.25yr 4/4 silty clay ped faces 5 mm thick; strongly acid, pH 5.2; very firm; pebbles 10%, rotted except those of quartz and chert; buried paleosol formed from Gravel II.

63–72 in. IB_{32mb} — Reddish brown 6.25yr 4/4 loam with few coarse light gray 10yr 7/1 mottles; weak fragipan with moderate coarse prismatic structure, verticle light gray 10yr 7/1 silty clay loam ped faces 20 mm thick; strongly acid, pH 5.4; firm; pebbles 5%, pebbles count, 67 pieces: hard chert 23%, weathered quartzite 16%, rotted granite 8%, unidentified ghosts 13%; buried paleosol formed from Gravel II.

72–80 in. IIA_{mb} — Faintly mottled yellowish brown 10yr 5/4 and pale brown 10yr 6/3 fine silt loam with many yellowish red 5yr 4/8 mottles and small black Mn stains; strong fragipan formed so that previous structure is obscure; firm; medium acid, pH 6.0; pebbles absent; buried paleosol formed from Sandy Alluvium.

80–94 in. IIB_{2gm} — Gleyed gray 10yr 6/1 silty clay with coarse streaks of yellowish red 5yr 4/8 silty clay loam in center of peds and many black Mn stains; strong fragipan formed so that former structure is obscure; very firm; slightly acid, pH 6.2; pebbles absent; buried paleosol formed from Sandy Alluvium.

94–113 in. IIB_{31mb} — Coarsely mottled reddish brown 6.25yr 4/3, strong brown 7.5yr 4/6 and light brownish gray 10yr 6/2 fine silt loam with large black Mn stains; strong fragipan with verticle gray 10yr 6/1 silty clay streaks 30 mm thick; neutral, pH 6.6; very firm; pebbles absent, gritty; buried paleosol formed from Sandy Alluvium.

113–126 in. IIB_{32mb} — Yellowish red 5yr 4/8 silty clay loam with streaks of gray 10yr 6/1 clay 50 mm thick forming 50% of soil mass, few black Mn stains appear in pattern of fine roots; strong fragipan, massive; neutral pH 6.6; no pebbles; buried paleosol formed from Sandy Alluvium.

126–135 in. IIB_{33mb} — Light brownish gray 10yr 6/2 silty clay loam; fragipan with strong very coarse angular blocky structure, thin yellowish brown 10yr 5/4 loam ped faces; neutral, pH 6.6; very firm; pebbles absent; buried paleosol formed from Sandy Alluvium.

135–168 in. IIC_{1b} — Light brownish gray 10yr 6/2 very fine sandy loam with few very coarse yellowish red 5yr 4/8 mottles; structure massive; hard when dry, non-coherent when moist; neutral, pH 7.0; pebbles absent; Sandy Alluvium.

168 in. + D — Sandstone bedrock, 804 ft elevation.

Note: A fragipan is a dense brittle soil layer developed beneath a B_2 or textural B horizon. The fragipan horizons of the buried soils, mentioned above, are believed to be a a result of secondary soil development process taking place after those horizons were buried by overlying soils. The above fragipan horizons are unusually thick and are believed to have been developed during several stages of the Pleistocene.

The 1000 Foot Terrace

A terrace at 1000 ft elevation occurs about 900 ft east of Globe Hill (fig. 1). Its surface is mantled with several feet of the Very Fine Sand and there are no excavations from which to study the paleosol of the gravelly material beneath. The gravelly material of this terrace appears to be similar to other terrace ma-

terial at a level of 1020 to 960 ft in the Upper Ohio Valley, except that elsewhere the mantle of Silt is much less conspicuous or has not been seen. Crystalline pebbles indicate its glacial origin.

Soils of the 1020 to 960 ft terrace at Vulcan and East End, Ohio, are now in process of study.

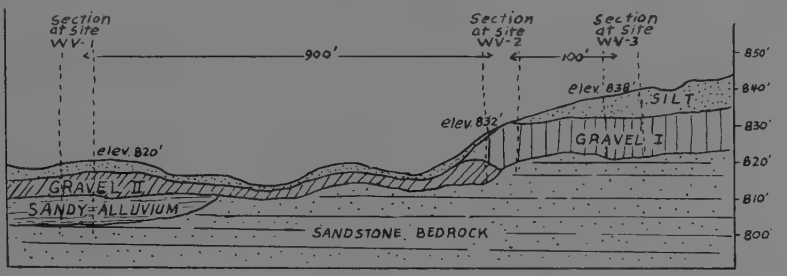

FIGURE 2. Cross section of Globe Hill looking eastward from the Ohio River.

DISCUSSION

The material of the 1000 ft terrace is presumably the oldest in the sequence and probably very early Pleistocene. Discussion of its composition and soils must await completion of investigations now underway at good exposures at Vulcan and East End.

The paleosols of site WV–3 are the most highly weathered, the most deeply buried and at the lowest elevation of the soils described. The Gravel II of paleosol I at site WV–3 is more weathered than the Gravel I at site WV–2. The buried paleosol II at site WV–3 is logically older yet, because it is buried by paleosol I. The fragipan horizons here are usually thick and may indicate very great age and a long period of soil development.

The arrangement of soils at sites WV-3 and WV–2 (fig. 2) and their parent materials indicates that Gravel II was weathered and partly removed before it was buried by Gravel I.

Gravel I lies over the soil of Gravel II at site WV–2. Thus, Gravel I must be of later origin. However, pebbles in Gravel I of granite and other rocks, except those of chert and quartz, at a 91 in. depth, are weathered so that they are soft or strongly altered. This weathering is more intense than that of Illinoian material several miles to the north, which at such a depth, contain granite pebbles that have only weathered rinds and sandstone pebbles that are oxidized but hard.

The 832 ft elevation of the soil of Gravel I and its degree of weathering are similar to a deposit behind the new supermarket in East End, Ohio (east part of East Liverpool). Here a sandy and gravelly glacial drift is leached more than 40 ft deep where it rests on bedrock.

A time interval is required, between the deposition of Gravel I and the silt, for the formation of paleosol I, formed from Gravel I at site WV–1. Gravel I is strongly weathered beneath the Silt in the IB_{21b} horizon.

While the soil formed from the Silt is the youngest soil here, if the colluvial A_1 horizon is omitted, it is still an old soil. It is leached to over a 71 in. depth, it has structure throughout its entire depth and has a colluvial surface.

The A_1 horizon, surface soil covering Globe Hill is of silt loam and contains sandstone channers and a few pebbles of crystalline rocks.

Colluvial soil layers are prominent in this region where terraces above 800 ft elevation provide a bench for colluvial material to accumulate. Such colluvium however is not prominent on lower terraces.

CONCLUSION

The soils of Globe Hill, except that of the surface colluvium, were formed before the Wisconsin stage of the Pleistocene.

The thin surface soil or A_1 horizon is part of a modern soil which is formed from colluvial material accumulated after other materials of Globe Hill were deposited.

The Silt is wind deposited material upon which is a soil more deeply developed than Wisconsin medium textured soils in the drainage basin of the Upper Ohio River. It is therefore considered to be pre-Wisconsin but not early Pleistocene. It may be Illinoian in age.

The soil formed from Gravel I is derived from glacial outwash that is probably pre-Illinoian in age as it is more deeply weathered than coarse textured Illinoian drift in the drainage basin of the Upper Ohio River.

The paleosol formed from Gravel II is older than the above soils as it is buried by them. Gravel II contains crystalline pebbles. However, it may be reworked, interglacial material rather than glacial outwash. It is older than Gravel I and pre-Illinoian.

The deeply buried paleosol underlying Gravel II is formed from a sandy alluvium that represents a stage of filling to at least 812 ft elevation at this place. It, too, may be an early Pleistocene inter-glacial deposit.

The terrace material 900 ft east of Globe Hill, at an elevation of 1000 ft, is similar to terrace material of glacial outwash at Vulcan and at East End, Ohio at 1020 to 960 ft elevation, except that it is buried by the Silt. This terrace is apparently still earlier and must be very early Pleistocene.

It is tempting to correlate the 1020 to 960 ft terrace materials as Nebraskan, those at 837 ft at Globe Hill (Gravel I) as Kansan, and those under Gravel I (Gravel II) as Aftonian interglacial material. However, positive affirmation must wait until the sequence of lower terraces (not present at Globe Hill, but developed elsewhere in the Ohio Valley) are worked out in detail. The lowest terraces at East Liverpool and elsewhere are certainly Wisconsin, and the soils of a higher terrace at 760 ft seem somewhat older and may be Illinoian in age. However, their soil morphology and correlation is yet to be worked out. It is felt that until the later Pleistocene dating is certain the dating of the still earlier terraces cannot be secure. Indeed, the status of the terms "Kansan," and especially "Nebraskan" is so uncertain in the eastern United States that these may not fit at all in the Ohio Valley, and that for a time local names will be preferable. However, this report infers that there are two, well separated, pre-Illinoian, glacial outwashes in the Upper Ohio Valley.

REFERENCES

Hubbard, G. D. 1954. Terrace interpretation in southeastern Ohio. Ohio Jour. Sci. 54: 365–377.

Ireland, H. A. 1940. New evidence for an Illinoian glacial boundary in northeastern Ohio. Geol. Sur. Soc. Amer. Bull. 51: 337–358.

. 1943. Pre-Illinoian glaciation in southeastern Ohio. Ohio Jour. Sci. 43: 180–181.

Leverett, F. 1902. Glacial formations and drainage features in Erie and Ohio basins. U. S. Geol. Sur. Monog. 41.

———. 1929. Topographic and geologic atlas of Pennsylvania. no. 5.

. 1934. Glacial deposits outside the Wisconsin terminal moraine in pennsylvania. Penna. Geol. Sur. 4th ser., Bull. G7.

Mayer-Oakes, W. J. 1955. Prehistory of the upper Ohio valley; an introductory archeological study. Anthropological series no. 2. Annal of Carnegie Museum, Pittsburgh, Pa. Vol. 34.

Stout, W. 1953. Age of fringe drift in eastern Ohio. Ohio Jour. Sci. 53: 183–189.

and **G. F. Lamb.** 1938. Physiographic features of southeastern Ohio. Ohio Jour. Sci. 38: 49–83.

OBSERVATIONS ON THE NATURAL HISTORY OF THE CHAIN PICKEREL (*ESOX NIGER*)

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INTRODUCTION

The eastern chain pickerel, *Esox niger*, was first introduced into Ohio when local sportsmen in the northeastern part of the State stocked seven hundred adults in Long Lake, Summit County, in 1935. The breeders came from New Jersey.

Long Lake is a natural body of water located in the lower level of the Portage Lakes chain, which supplies water for industrial use in South Akron. The Lake is 935 feet above sea level and has an area of 225 surface acres. The shoreline is approximately six and one-half miles in length.

The Lake has a maximum depth of approximately forty feet, and 17 percent of the surface area is less than ten feet in depth. This shallow zone is filled with various types of vegetation such as cattail (*Typha* spp.), bulbrush (*Scripus* spp.), smart weed (*Polygonum* spp.), parrot feather (*Myriophyllum* spp.), hornwort (*Ceratophyllum* spp.), chara (*Chara* spp.), white water lily (*Castalia tuberosa*), spatterdock (*Nuphar* sp.), water loosestrife (*Lysimachia* spp.), and curlyleaf pondweed (*Potamogeton crispus*).

FIGURE 1. Chain Pickerel (*Esox niger*) from Long Lake. Male (left) Female (right).

The northwest margin of the lake is a large marsh. Lake bottom types are chiefly muck and peat, but small areas of sand and silt are present.

The fish population of Long Lake consists chiefly of bluegill, (*Lepomis macrochirus*), crappie (*Pomoxis annularis* and *P. nigromaculatus*), gizzard shad (*Dorosomia cepedianum*), largemouth bass (*Micropterus salmoides*), and smaller numbers of brown bullheads (*Ameiurus nebubosus*), carp (*Cyprinus carpio*), yellow perch (*Perca flavescens*), warmouth (*Chaenobryttus coronarius*), and western chub suckers (*Erimyzon sucetta kennerlyi*).

METHODS AND MATERIALS

An intensive effort was made in 1951 to obtain detailed information on the life history of the chain pickerel. Modified fyke nets, described by Roach (1942) were used in obtaining specimens for study. Pickerel were tagged, measured to the nearest half inch, weighed in grams or ounces, and scale samples collected for age-growth studies. Spawning observations were attempted in the field, but to facilitate such study, breeders were moved from Long Lake into a pond at the Akron Fish Farm.

Air and water temperatures and transparencies were obtained each morning and evening in the breeder pond.

No body-scale relationship was calculated, but scale samples were consistently taken from the area above and behind the pectoral fins at approximately one-third the distance from the pectoral fin joint and the anterior point of attachment of the dorsal fin. The growth was calculated on the assumption of direct proportion between the scale measurements and the length of the fish at the time of annulus formation.

TABLE 1

Take of chain pickerel by fyke nets in Long Lake

Year	Number	Length Range Inches	Water Temperatures Fahrenheit	Hours Fished
1948	2	16.0–20.5	73	168
1949	11	14.5–23.0	48–55	120
1950	9	15.0–20.5	37–68	214
1951	27	11.0–22.0	39–68	636
1952	48	10.5–24.0	38–46	648
1953	12	13.0–23.5	42–50	110
1954	17	11.5–24.5	48–54	204
1956	3	16.0–25.0	46–48	70

RESULTS

Habitat and Distribution

Chain pickerel were taken in fyke nets in Long Lake. The nets which took pickerel were in or near the marshes, in narrow channels or near heavy vegetation. Webster (1942) described their habitat as weedy areas. Most of the pickerel were taken in March and April when water temperatures ranged from 37 to 68° F (table 1).

One chain pickerel was taken in November, 1957, from Nesmith Lake, one mile down a canal from Long Lake.

They prefer the deeper cooler waters during mid summer but move into the shallow weedy areas in the fall when the water cools. Very few pickerel have been taken in nets located in shallow waters after May. A definite movement into the marshy spawning areas occurs in spring shortly after the ice leaves the lake, usually in March or April. Embody (1918) found such movements in Cayuga Lake, New York at the end of March. The ratio of males to females taken during this season of the year in Long Lake was 1:1, but it may not be typical because of the small samples.

Spawning

To provide for closer observations on the spawning habits, four males and four females, ranging from 14 to 25 in. in length, were placed in a vegetated pond

0.6 acres in surface acreage at the Akron Fish Farm in April, 1951. Observations were made during all hours of the day and night. The first spawning was seen at 9:45 A. M. on April 10. The water temperature was 44° F. Spawning occured over a mass of willow roots in vegetation. On April 11, spawning was noted at 5 P. M. Embody (1918) reported spawning at a temperature approaching 47° F.

Those spawning groups observed were comprised of only one male and one female. The fish swam side by side, weaving in and out among the vegetation. The male turned his ventral side toward the female and appeared to bump her. At this time the female turned her ventral side toward the male, and the eggs were laid with what appeared to be a lashing of their tails. The male appeared to initiate the action.

On April 25, eggs were found scattered over willow roots and vegetation in the pond; paired fish were observed at this time but spawning was not. Water temperatures ranged from a low of 36° to a high of 72° F during the period from April 10 to April 25.

Although Webster (1942) reported the incubation to be from a week to ten days, according to water temperature, fry were found in the pond on the first of May. As reported by Underhill (1949) fry were found lying on vegetation, but some appeared to be clinging to the surface scum on the hatchery ponds.

TABLE 2

A comparison of the calculated age growth of chain pickerel from Long Lake with that reported from other states

State	Average calculated total length at each annulus						
	1	2	3	4	5	6	7
Massachusetts*	7.1	11.1	14.0	16.4	18.4	20.4	
Connecticut**	7.3	11.0	14.0	16.6	18.6	20.6	
Ohio	5.7	10.6	14.0	16.0	17.4	20.3	20.7

*Carlander, 1950.
**Thorpe—Correspondence.

Age Growth

Gizzard shad and western lake chub suckers were stocked in the hatchery pond to provide food. The pond was drained September 10, 1951. The fingerling ranged from 2.8 to 8.8 in. in length and averaged 4.2 in. They ranged from 1 to 44.5 gm in weight. A growth of 4½ in. in length at one year of age was reported in the Massachusetts Fish Commission's report for 1870. Raney (1942) reported the total length of specimens taken in Rensselaerville, New York to have ranged from 3.2 to 4.7 in. on September 22. Correspondence with Lyle M. Thorpe, State Board of Fisheries of Connecticut, indicates a growth of approximately 7.3 in. for the first year's growth. Age growth data for adult Long Lake fish indicates a slightly slower growth than Thorpe's Connecticut estimates of age growth for that State (table 2).

A significant difference in the growth of female chain pickerel over that of males was found after the second year. This also is found in the northern pike. The limited size of the sample of each sex may have greatly influenced the data on the growth relationship.

LITERATURE CITED

Carlander, K. D. 1950. Handbook of freshwater Fishery Biology. Wm. C. Brown Company, Dubuque, pp. 281.

Embody, G. C. 1918. Artificial hybrids between pike and pickerel. Jour. Hered. 9: 253–256.
Raney, E. C. 1942. The summer food and habits of the chain pickerel (*Esox niger*) of a small New York pond. Jour. Wildl. Mgt. 6: 58–66.
Roach, L. S. 1942. The Fish populations of Buckeye Lake as determined by trap nets. Ohio Jour. Sci. 42: 237–245.
Underhill, A. H. 1949. Studies on the development, growth, and maturity of the chain pickerel. (*Esox niger*) LeSueur. Jour. Wildl. Mgt. 13: 377–391.
Webster, D. A. 1942. The life histories of some Connecticut fishes. In a Fishery Survey of Important Connecticut Lakes. Conn. Geol. and Nat. Hist. Surv. Bull. No. 63: 1 339 (122–207).

A NEW SPECIES OF *BASICLADIA* FROM THE SNAIL *VIVIPARUS MALLEATUS* REEVE

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The Genus *Basicladia* of the Chlorophyta has been known for its specificity of habitat; the carapace of turtles. The alga was first described from turtles collected in Michigan by Collins (1907) who placed it in the Genus, *Chaetomorpha*. In 1909 he again reported it from turtles collected in Massachusetts and Tiffany (1926) reported it from Iowa.

Hoffman and Tilden (1930), studying material collected in Minnesota, noticed a regular tendency of branching in the basal holdfast cells of the algae. This basal branching, which was also described by Collins (1907), did not correlate with the characteristics of *Chaetomorpha*. The alga was redescribed as the Genus, *Basicladia*.

The genus contained two species which were separated by the diameter of the coenocytes and the relative length of the filaments. *Basicladia crassa* Hoffman and Tilden, has a coenocyte diameter range of 50 to 120 μ while the filament length ranges up to 2 cm. *Basicladia chelonum* (Collins) Hoffman and Tilden has a coenocyte diameter range of 20 to 35 μ from the base to the apical cell, and a filament length of approximately 2 mm. Later, N. L. Gardner (1937) described a new alga, *Chaetomorpha sinensis*, which G. M. Smith (1950) reassigned to the genus *Basicladia*. *Basicladia sinensis* (Gardner) G. M. Smith has a coenocyte diameter range of 60 to 95 μ while the filament length ranges from 8 to 12 cm. The members of this genus have cells which are irregular, anastomosing, and with rhizoidal tendencies. The upright filaments arise sporadically from the holdfast cells. The individual coenocytes of a filament become shorter and broader from basal to apical region resulting in a definite clublike appearance. Zoospores escape through a lateral pore from sporangialike cells usually located in the upper part of the filament.

On June 21, 1956, a specimen of *Viviparus malleatus* Reeve was taken from Terwillegar's Pond on South Bass Island, Lake Erie. Routine examination of the algae growing on the shell disclosed one that resembled a described species of the Genus, *Basicladia*. This was odd as the known species of the genus were well-known for their specificity of habitat; the carapace of turtles. This discovery instigated a more intense study of the alga.

The alga consisted of clumps of nonbranching upright filaments having approximately 12 to 20 cells. The gross appearance of the clump is extremely diminutive and appears as "moss patches" under a magnification of 150 X. The shape of the cells is distinctive as they become progressively shorter and boarder towards the apex of the filament. This results in the characteristic clublike outline which is characteristic of the genus and is in direct correlation to the described species on turtles.

The upright filaments arise from a loose basal mat composed of irregular cells which exhibit a tendency towards polygonal outline. The basal cells create a bed of anastomosing, rhizoidal-like branches which produces the "moss patch" effect on the substrate. The upright filaments arise indiscriminately from the individual cells of the basal mat. The chloroplast is smooth in the lower vegetative cells but is granulated and coarse in the upper coenocytes of the filament. However, the chloroplast is a reticulum in both when observed under oil immersion. These granulated cells progress from ovular in the mid-filament region to sperhical at the distal end. Many of the cells have a small, lateral, papillose swelling that later terminates in a pore. They should probably be considered as being sporangia. This is in agreement with the description of the turtle species by Hoffman and Tilden.

The habitat of the host snail, *Viviparus malleatus*, is a small, shallow pond which is continuous with Lake Erie by means of a narrow channel. The pond is fairly well infested with both emmergent and submerged aquatic vegetation, and the bottom consists of mud and silt. At times, heavy wind action on the lake indirectly causes periods of water-level fluctuation and turbidity in the pond. The host snails, for the most part, are distributed along the shallow west and south pond margins. Most of the specimens collected were covered with a liberal amount of silt and mud.

The following culture system was adopted in an attempt to determine whether the alga discovered on the snail constituted a new and separate species of the Genus, *Basicladia*. Several slant cultures, of both the snail and turtle species, were prepared utilizing an inorganic agar base and the sterilized scrapings from the shells of both the host snail and turtles. Three patches per culture tube of either turtle or snail periostricum scrapings were placed directly on the agar. The tubes were then innoculated with a *Basicladia* specimen. Control tubes containing only the agar base were also prepared. All the tubes were kept moist and plugged with sterile cotton. The types of cultures and the respective results are given below. In each instance the word "Material" indicates the respective shell scrapings.

1. *Snail* Basicladia *on Snail Material*.—The alga grew very well. The filaments increased in length from approximately 50 μ to 370 μ. At this point linear growth ceased although the nutritive material seemed to be plentiful. The upper coenocytes increased in width and attained a sperhical shape. The chloroplast became granulated and the whole seemed to resolve into a sporangium. At this point a tendency existed for the filaments to break into their component coenocytes. This particular condition was observed in all cultures whether they were of the snail or of the turtle species.

2. *Snail* Basicladia *on Turtle Material*.—The alga grew very well but did not attain a size beyond that of an average filament from the host snail. The filaments and the individual coenocytes behaved as those in culture type 1.

3. *Turtle* Basicladia *on Snail Material*.—The alga did not exhibit any appreciable growth although it continued to survive. It is possible that a growth substance exists in the snail material and that it supplies only the minimum requirements for this particular species. This limiting factor, if such a factor exists at all, may explain the absence of the turtle species of *Basicladia* on the *Viviparus* snail.

4. *Turtle* Basicladia *on Turtle Material.*—The alga grew very well and completely covered the patches of carapace scrapings. The filaments attained an approximate length of 1/6 cm.

5. *Snail* Basicladia *on Plain Agar Base.*—The alga did not grow at all. At the end of approximately 30 to 40 days it died.

The dimensions of the filaments, as well as those of the individual coenocytes, were distinctly different than those of the known *Basicladia* species. The coenocyte diameter ranged from 5 to 28 μ from basal to apical coenocyte. An average filament was approximately 0.3 mm in length from primary to apical coenocyte.

Since the morphological characteristics of this epizooic alga on the snail correlated definitely with the requirements of the Genus, *Basicladia*, it was identified with this genus. However, since the habitat of this alga is opposed to the known specific habitats of the described species, *B. sinensis*, *B. crassa*, and *B. chelonum*, and the diagnostic diameter size range is definitely below these species, and furthermore, since the cultures showed that the snail alga was specific and unique to its type habitat, the alga is proposed as a distinct and new species of the Genus, *Basicladia*.

Summary of Species

On Turtles:

1. Upright filaments reaching a diameter of 60–95 μ; filament length 8–12 cm..... *B. sinensis*
2. Upright filaments reaching a diameter of 50–120 μ; filament length 1–2 cm..... *B. crassa*
3. Upright filaments reaching a diameter of 35 μ or less; 12–20 μ at base *B. chelonum*

On Snail, Viviparus malleatus:

4. Upright filaments reaching diameter of 28 μ or less; 5–10 μ at base..... *B. vivipara*

Basicladia vivipara sp. nov.

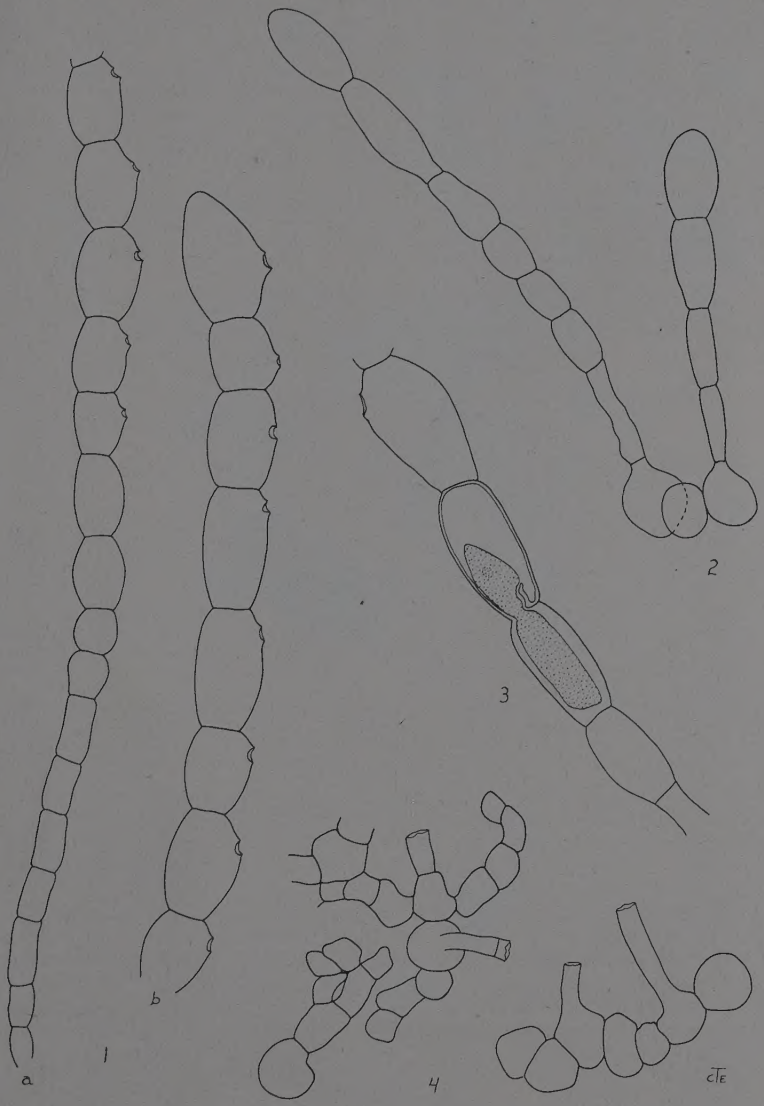
Filamentis erectis 0.3 to 0.35 mm alta; filamentis amplis, septatis, prostratis, irregularibus plus minusve ramosis adjunctis; filamentis substrato superficiebus adhaerentibus; filamentorum erectorum segmentis basim 5 to 10 μ diametro, superne diametro 28 μ.

Filaments green; upright filaments fairly rigid, clubshaped, clumped; individual coenocytes of filaments becoming shorter and broader from base to apex; chloroplast of basal coencyte smooth under low magnification, reticulate under oil immersion; chloroplast of medial to apical coenocytes coarse and granulated; apical cells become sporangia; filament length approximately 0.3 to 0.35 mm; coenocytes diameter 5 to 28 μ from base to apical coenocyte, basal coenocytes 5 to 10 μ; upright filaments nonbranching, primary basal coenocyte confluent with coenocytic substrate mat; mat showing rhizoidal tendencies; upright filaments arising indiscriminately from rhizoidal cells; rhizoidal cells irregular with polygonal tendencies, diameter range 1.2 to 12.2 μ.

Habitat: Shell of *Viviparus malleatus*, Terwillegar's Pond, South Bass Island, Put-in-bay, Ohio. Collected June 21, 1956 by Elizabeth Williams.

Type: At The Ohio State University, Botany and Zoology Departments, Columbus, Ohio.

Basicladia vivipara thrives on the snails during the summer months, but by the end of this period the filaments seemed to be disappearing. During the winter months the host snail, which was kept in an aquarium, was subjected to fairly continuous light and a constant temperature. Examination of the shell of the snail showed what appeared to be rhizoidal mats, but no filamentous growth was observed. Shortly thereafter the snail died. Growth over a short period



EXPLANATION OF FIGURES IN PLATE

1. a-b. Mature, erect filament showing lateral pores.
2. Young filament showing attachment to basal cells.
3. Portion of mature filament showing protoplast of one cell entering the cell above. Note the broken cross wall.
4. Prostate branching system showing the remains of four upright filaments.

was observed during the spring on the empty shell that had been left in the aquarium. The shell was degenerating, and the green clumps soon disappeared. It is significant that the alga growth was observed only on the larger snail specimens collected. There is a possibility that the periostricum of the snail shell contains a growth factor for the characteristic growth of this alga. Its presence in sufficient quantity on the large snail versus that on a small snail is directly correlated with the previous observation. With this fact in mind, a turtle should be a suitable habitat for the species. Perhaps it does exist in such a habitat, but due to its minute size it has been overlooked.

The questions pertaining to the life history, distribution, and growth-host-size relationship warrant further study. It is hoped that present information can be supplemented by further investigation.

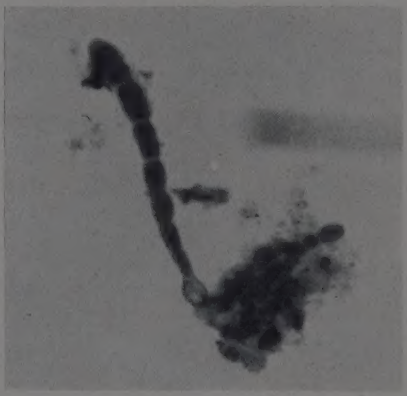


FIGURE 5. Photomicrograph of *Basicladia vivipara* Normandin and Taft showing the club-like appearance of the filament (Approx. ×128).

SUMMARY

In June 1956 a specimen of the snail *Viviparus malleatus* Reeve was obtained from a pond on South Bass Island, Lake Erie. An alga growing on the snail shell was identified with the Genus, *Basicladia* described by Hoffman and Tilden (1930). This habitat is new for this genus which previously had been recorded as being present only on the carapace of turtles.

The alga was cultured in an effort to determine whether it represented a new species for the genus. The culture technique consisted of agar slant tubes upon which were placed sterilized shell scrappings from both turtles and the *Viviparus* snail. The tubes were then innoculated with the alga.

It was determined from these cultures that the alga was unique and specific to the genus both in species characteristics and habitat. It was described as the species *Basicladia vivipara.*

REFERENCES

Collins, F. S. 1907. Some new green algae. Rhodora 9: 198–200.
Gardner, N. L. 1937. New species of *Chaetomorpha* from China. Madrono 4: 28–32.
Hoffman, W. F. and **J. F. Tilden.** 1930. *Basicladia*: a new genus of Cladophoraceae. Bot. Gaz. 89: 374–384.
Smith, G. M. 1950. Freshwater Algae of the United States. McGraw-Hill Book Co., N. Y. pp. 217–218.
Tiffany, L. H. 1926. The filamentous algae of northwestern Iowa with special reference to the Oedogoniaceae. Trans. Amer. Micr. Soc. 45: 78.

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